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ANALYSIS OF BEST MANAGEMENT PRACTICES FOR STORM WATER COMPLIANCE AT AIR FORCE AIRFIELDS

THESIS

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THESIS

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Abstract

This research analyzed storm water best management practices (BMPs) that may assist Base Civil Engineers/Environmental Managers in complying with National Pollutant Discharge Elimination System (NPDES) storm water discharge requirements for Air Force airfield pavements. As a result of recent storm water regulations issued by the Environmental Protection Agency, increased emphasis has been placed on preventing and controlling the discharge of pollutants into surface waters of the United States. Based on the results of an American Association of Airports Executives' survey of civilian airports, the types and levels of airfield pollutants were identified. Typical NPDES storm water permit standards were then established based on actual permits from Air Force bases and civilian airports. A thorough literature search revealed the nonstructural, low-structural, and structural BMPs capable of eliminating or reducing storm water pollutants. Finally, a Decision Support Framework (DSF) was introduced that guides a decision-maker through a series of tables that narrows the appropriate BMP options for a particular site or installation. The DSF encompasses factors such as pollutant removal effectiveness, watershed area, soil permeability, storm water discharge controls, restrictions on BMPs, and community and economic factors.

ANALYSIS OF BEST MANAGEMENT PRACTICES FOR STORM WATER COMPLIANCE AT AIR FORCE AIRFIELDS

I. Introduction

This chapter provides background information on the general issue of nonpoint source (NPS) pollution at an airfield. It then discusses the rules and regulations governing storm water runoff and their applicability to the United States Air Force (USAF). Finally discussed in this chapter are the specific problem, investigative questions, and scope and limitations for this research. Definitions of key terms may be found in Appendix C.

General Issue

In 1972, Congress passed the Federal Water Pollution Control Act as the basic framework for federal water pollution control. This Act was renamed the Clean Water Act (CWA) in 1977 and its objective was to "restore and maintain the chemical, physical, and biological integrity of the nation's water" (Arbuckle and others, 1991:69). The discharge of any pollutant to navigable waters was prohibited unless the discharge was authorized by a National Pollutant Discharge Elimination System (NPDES) permit. The objective of the NPDES program was to reduce the discharge of point source pollutants from industrial process wastewater and municipal sewage (US Congress, 1990:47990).

The Environmental Protection Agency (EPA) conducted a study in 1986 on the effectiveness of the CWA in improving the quality of our nation's waters. The EPA concluded that our nation's waters were still polluted and the water quality problems were largely attributed to

pollution from nonpoint sources (Cabe and Herriges, 1992:134; GAO, 1990:8). In an effort to remedy this situation, the Water Quality Act (WQA) of 1987 amended the CWA to "improve water quality in the areas where compliance with nationwide minimum discharge standards was insufficient to assure attainment of the CWA's water quality goals" (Arbuckle and others, 1991:65). Included in the WQA was the requirement for a NPDES permit for storm water runoff from municipal and industrial discharges.

In November 1990 the EPA began to implement section 405 of the WQA of 1987, which requires the EPA to establish regulations setting forth NPDES permit requirements for storm water discharges associated with industrial activity. All USAF bases are categorized as industrial dischargers and must comply with storm water standards and criteria established by the EPA (US Congress, 1992:41345). Instead of obtaining individual permits for every USAF base, the USAF has applied for a group or general permit. These permits were established to "allow certain classes of industries to reduce costs by requiring quantitative sampling data only from selected members of the group" (Isco, 1992:3). The permit requirements, due from the EPA by October 1993, will be based on the sampling of 15 different bases throughout the country.

Currently, many problems exist within the USAF in regards to meeting NPDES storm water standards. One problem area for a typical base is storm water runoff from the airfield. Various airfield activities discharge pollutants into surface waters. Some of them include de-icing of aircraft and runways, pollution from fire-fighting training exercises, and oil/fuel spills (Ryding, 1992:118).

In the future, permitting priorities of the EPA and the states will focus on "general aviation, reliever, air taxi, and military airports with at least 1[illegible].000 operations per year" (Whitescarver and Mackenthun, 1990: 9). The USAF must be prepared to meet NPDES requirements and prevent future violations, large fines, or restrictions

on routine airfield operations. Best management practices (BMPs), which are "measures or practices used to reduce the amount of pollution entering the surface water" (US EPA, 1992c:1-4), may be implemented to help an AF base meet its NPDES requirements.

Specific Problem

The purpose of this research is to analyze storm water best management practices to assist Base Civil Engineers/Environmental Managers in complying with NPDES storm water discharge requirements for airfield pavements.

Investigative Questions

The investigative questions associated with this research are:

1. What are the applicable rules and regulations associated with storm water runoff at airfields?
2. What are the types and levels of storm water pollutants generated from airfield activities?
3. What management practices can be implemented at USAF airfields to ensure compliance with future NPDES storm water requirements?

Scope and Limitations

This research examines relevant storm water regulations and the associated Air Force guidelines. Since USAF bases exist in many states and NPDES standards vary from one state to another (although the state standards must be at least as stringent as the federal standards), this research is limited to federal requirements that are common to all storm water permits, not the state or local regulations that bases must also follow. (US EPA, 1992c:1-1).

The research then reviews the nonstructural, low-structural, and structural best management practices available to reduce storm water contamination. The scope is limited to those methods applicable to airfield activities and their associated pollutants.

A major assumption of this research is that the pollutants and BMPs related to airfield pavements within the Air Force closely parallel those at civilian airports. Thus, data obtained from civilian airports are readily transferable and characteristic of Air Force bases.

II. Literature Review

This chapter will provide a detailed description of the literature concerning storm water runoff at an airfield. Nonpoint source (NPS) pollution will be discussed first, followed by an overview of the legislation which applies to NPS pollution control. National Pollutant Discharge Elimination System (NPDES) permits will then be described in detail. Airfield pollutants and activities that produce such pollution will also be examined. Lastly, best management practices (BMPs) to control storm water runoff will be discussed.

Nonpoint Source Pollution

Part of the environmental movement during the 1970's was focussed on visible forms of water pollution. Lakes and rivers were so polluted that some, like the Cuyahoga River in Cleveland, Ohio, caught fire (Masters, 1991:101). In an attempt to control water pollution, Congress passed the Federal Water Pollution Control Act (FWPCA) of 1972. Early management efforts concentrated on industrial and municipal point sources because they were easy to identify and their control was possible with current treatment technologies. Although significant efforts were made to clean up the nation's waters, "states continued to identify significant portions of waterways that were still not fit for designated uses such as fishing and swimming" (GAO, 1990:8). Today, most point source discharges have been reduced and it is "increasingly clear that control of nonpoint, or diffuse, sources is necessary to improve water quality further" (Reinelt and others, 1990:15).

The Environmental Protection Agency (EPA) defines nonpoint source (NPS) pollution as "diffuse pollution resulting from land runoff, precipitation, atmospheric deposition, drainage, or seepage, rather than a pollutant from a specific, single location" (GAO, 1990:8). NPS pollution can also be defined as:

> ...pollution that is transported from the land surface by means of direct runoff during and immediately after rainfall and or snow events; NPSs also include substances carried to the surface water via groundwater discharges. (Walesh, 1989:218)

NPSs have been cited as the cause of impairment of approximately "76 percent of lake water acres, 65 percent of stream miles and 45 percent of estuarine acres" (US EPA, 1989:vi; Heatwole and others, 1991:1). This has led to increased EPA concern for potentially toxic health and ecological effects from many of the pollutants being detected in these waters. Proof of this concern is an EPA study of 18 of the 24 most important environmental problems. This study, conducted by the EPA's Office of Policy, Planning, and Evaluation, concluded that the overall risk from NPSs is generally more serious than those from point sources. The health risks were nearly equal, but the ecological risks posed were "identified as a more serious problem" (GAO, 1990:50).

There are other problems associated with NPS pollution besides health and ecological risks, such as:

- Ground and surface water contamination,
- Water storage reduction,
- Commercial and sport fisheries destruction, and
- Water's aesthetic qualities degradation. (US EPA, 1990:1)

The EPA, in an attempt to get a better handle on the problem of NPS pollution, grouped the primary sources of pollution into seven categories. The categories, along with the percentage of NPS pollution attributed to each, are as follows:

- Agriculture (50-70%),
- Urban Runoff (5-15%),
- Hydromodification (5-15%),
- Resource extraction (1-10%),
- Silviculture (1-5%),
- Construction (1-5%), and
- Land disposal (1-5%). (Cheremisinoff, 1990:216; GAO, 1990:8)

As shown above, agriculture contributes approximately 50-70 percent of NPS pollution to surface waters, four times that of any other category. Urban runoff, which more closely parallels runoff from an Air Force base because of residential, shopping, administrative, recreational, and

airport areas, is the second largest contributor of NPS pollution at 15 percent.

Legislation

Congress passed the Federal Water Pollution Control Act (FWPCA) of 1972 to provide the basic framework for federal water pollution regulation. At that time, the EPA was given the responsibility for setting nationwide effluent standards for industries based on the capabilities and costs of control technologies (Arbuckle and others, 1991:68). Although significant progress in controlling water pollution was made, more efforts were needed to improve water quality.

Amendments to the FWPCA were passed by Congress in 1977. The amendments were entitled the Clean Water Act (CWA) of 1977. The CWA's objective was to restore the water quality in the U.S. by "prohibiting the discharge of any pollutant to navigable waters from a point source unless the discharge is authorized by a NPDES permit" (US Congress, 1990:47990). National goals to achieve this objective, based on both the 1972 act and the 1977 amendments, include:

- Eliminate discharges of pollutants into navigable waters by 1985,
- Make the nation's waters suitable for recreation and fish and wildlife propagation,
- Eliminate discharges of toxic pollutants in toxic amounts, and
- Provide incentive for major research and demonstration efforts to develop the technology necessary for eliminating discharge of pollutants into navigable waters, water of the contiguous zone, and the oceans. (Novotny and Chesters, 1981:19)

Between 1978 and 1983, the EPA funded studies, known as the Nationwide Urban Runoff Program (NURP), to measure pollutants in urban storm water runoff. The results indicated that storm water runoff in urban or industrial areas carries pollutants to nearby lakes and streams (Isco, 1992:2). Another study, entitled the National Water Quality Inventory: 1986 Report to Congress, evaluated the impact of the CWA. The report concluded that there were still water quality problems throughout the country and they were largely attributable to pollution

from nonpoint sources (GAO, 1990:8). Thus, one of the main reasons the Water Quality Act (WQA) of 1987 was passed was to control NPS pollution.

WQA of 1987. Over numerous vetoes by President Reagan, who said that "the real issue at hand is not clean water but the federal deficit," Congress passed Public Law 100-4 (Kovalic, 1987:36). The following discussion of the WQA will outline its basic objective, administrative and judicial enforcement options, and the key provision concerning NPDES permits.

Basic Objective. The WQA's basic objective is to "improve water quality in areas where compliance with nationwide minimum discharge standards was insufficient to assure attainment of the Clean Water Act's water quality goals" (Arbuckle and others, 1991:65). More particularly, it attempts to:

- Tighten discharge standards beyond technology-based minimums to ensure water quality standards for toxic pollutants are met,
- Enhance enforcement authority with increased penalties (civil, criminal, and administrative), and
- Recognize the pollution problem of non-point sources. (Kovalic, 1987:36)

Enforcement Options. The 1987 amendments also strengthened the enforcement options for the EPA and the states. These are important for AF managers to understand because violations and/or negligence can become very costly. It is even possible for Air Force individuals to be severely fined or imprisoned, primarily those in high managerial positions like Base Commanders and Base Civil Engineers (Thompson, 1992). The major components of the Act regarding enforcement are:

1. Section 309(g) provides for a two-tier administrative penalty from the EPA modeled after the 1986 Superfund amendments, which are concerned with the cleanup of past hazardous waste sites.

- Tier I applies regardless of the number of violations or days. The fine goes up to $10,000 per penalty not to exceed $25,000. There is also an opportunity for an informal hearing.
- Tier II is different in that the penalty may not exceed $10,000 per day of violation with a maximum of $125,000. There is also an opportunity for a formal hearing through the Administrative Procedure Act. (Kovalic, 1987:41)

2. EPA has the new authority to assess civil penalties. This authority applies to violations of Sections 301 and 302 which include standards for water quality (Kovalic, 1987:38).

3. Section 309 was also amended to provide more stringent criminal and civil judicial penalties based on the degree and intent of the violation. There are 4 types of criminal penalties:

- Negligent violation - subject to fine of $2,500 to $25,000 per day of violation, one year imprisonment, or both. Includes negligent violation of the sections listed above or negligent introduction into a public sewer system of any pollutant or hazardous substance.
- Knowing violation - fine of $5,000 to $50,000 per day, three years imprisonment, or both.
- Knowing endangerment - fine of $250,000, maximum imprisonment of 15 years, or both. In the case of an organization, the fine is not greater than $1 million.
- False statements - fines of not more than $10,000 or imprisonment for not more than 2 years, or both.

Civil penalties were also raised from $10,000 per day of violation up to $25,000 per day of violation (Arbuckle and others, 1991:120).

The WQA also sets forth factors to weigh in assessing the appropriate amount of civil penalties against a violator. Included are:

- The seriousness of the violation,
- The economic benefit resulting from the violation,
- Any history of such violations,
- Any good faith efforts to comply with applicable requirements,
- The economic impact of the penalty on the violator, and
- Such other factors as justice may require. (Arbuckle and others, 1991:123)

Key NPS Pollution Provision. The key provision of the WQA of 1987, with regard to NPS pollution, is summarized under Section 405. It states that the EPA is required to "promulgate final regulations governing storm water permit application requirements for storm water discharges associated with industrial activity" (US Congress, 1990:47992). The application requirements for NPDES permits, which vary based on the type of permit and the industrial activity, will now be discussed.

National Pollutant Discharge Elimination System for Storm Water

In an effort to control nonpoint source pollution, the EPA issued storm water regulations on November 16, 1990. These regulations, which apply to both municipal and industrial storm water discharges, define who must apply for and obtain a NPDES permit for storm water discharges. These permits "will allow the States and EPA to track and monitor sources of storm water pollution" (US EPA, 1992c:1-5).

The facilities that fall under the jurisdiction of the new regulations are classified into eleven categories by their Standard Industrial Classification (SIC) code. Air Force airfields are categorized under *SIC 45--Transportation by Air*. This category applies to "transportation facilities which have vehicle maintenance shops, equipment cleaning operations or aircraft deicing operations" (US Congress, 1990:48013; Department of the Air Force, 1993).

Some early problems existed when industries tried to classify their activities into the SIC codes. It was argued that if gasoline stations were not considered for permitting, then transportation facilities should be exempt. The EPA disagreed and stated:

> Transportation facilities such as bus depots, train yards, taxi stations, and airports are generally larger than individual repair shops, and generally engage in heavier more expansive forms of industrial activity. In keeping with Congressional intent to cover all industrial facilities, permit applications from such facilities are appropriate. (Jensen, 1991:21; US Congress, 1990:48013)

Thus, airfields are considered industrial facilities and must obtain a NPDES permit for its pollutants.

The three types of NPDES permits for storm water discharges associated with industrial activity are general group, or individual.

General Permit. A general permit is a "permit issued under the NPDES program to cover a certain class or category of storm water discharges. These permits allow for a reduction in the administrative burden associated with permitting discharges" (US EPA, 1992c:B-2). The permits may be issued by the Federal EPA for States that do not have

NPDES permitting authority. Permitting authority is granted from the Federal EPA to States that have established programs to control pollutant discharges into US waters. States that have NPDES and general permit authority may write their own general permits or use the Federal permit. Initially, though, the EPA intends to:

> ...issue general permits that initially cover the majority of storm water discharges associated with industrial activity in States without authorized NPDES programs. These permits will also serve as models for States with authorized NPDES programs. (US Congress, 1990:48002)

Once a general permit is developed and the public has had an opportunity to comment on permitting activities, industries must submit a notice of intent (NOI). A NOI is a notification to the permitting authority of a facility's intention to be covered by a general permit. It also exempts the facility from having to submit an individual or group application. The permitting authority then authorizes eligible industries to discharge under the permit conditions. If a general permit is not available before the deadline for an individual permit, industries will be required to obtain an individual permit. Also, industries in States which have NPDES authority only are not eligible for a general permit and must apply for an individual or group permit (US EPA, 1992c:B-4).

Group Permit. This option provides group participants with similar storm water discharges an alternative mechanism for applying for a permit. It also allows certain classes of industries to reduce costs by only requiring quantitative data from 10% of a group of more than 100 members (Isco, 1992:3; Whitescarver and Mackenthun, 1990:3). Group applications consist of two parts. Part 1 is non-quantitative information on group members and their locations. Part 2 requires quantitative data from water samples taken at selected locations. The deadline for submitting Part 1 to the Federal EPA was 30 September 1991. The deadline for Part 2, initially 18 May 1992, was extended until 1 October 1992 (US Congress, 1990:48003).

There are some advantages for participating in the group application process:

1. The procedure provides adequate information for issuing permits for certain classes of storm water discharges associated with industrial activity.

2. It is a way to reduce the costs and administrative burdens associated with storm water permit applications.

3. It reduces the burden on the regulated community by requiring the submission of quantitative data from only selected members of the group.

4. It consolidates information for reviewing permit applications and for developing general permits suited to certain industrial groups. (US Congress, 1990:48021)

Individual Permit. These applications must have been submitted to local permit authorities before 1 October 1992. This application is intended to be used in "developing the site-specific conditions generally associated with individual permits" (US Congress, 1990:48003). The application consists of two parts - EPA Forms 1 and 2F. Form 1 requires general information such as name, address and SIC code for the facility. Form 2F requires quantitative sampling, site maps, and a description of pollutant sources and exposed materials (Isco, 1992:3).

USAF Participation. As of 9 September 1992, the EPA had issued general permits for 11 unauthorized states: Alaska, Florida, Louisiana, New Hampshire, Oklahoma, Texas, Arizona, Idaho, Maine, New Mexico, and South Dakota. Bases in these states must apply for a Federal general permit since their states have not received permitting authority. Currently, most of the other states with general permitting authority have some sort of general permit in the making. Some already have final drafts, while others have proposed or staff drafts. Thirteen bases do not have general permits in States with permitting authority, primarily those in Colorado, Kansas, Michigan, Massachusetts, N. Carolina and Delaware (Department of the Air Force, 1993).

Fifteen USAF bases, or 10% of 151 total bases, sent storm water samples to the EPA as part of a group permit application. Data from these bases will be used by the EPA to write a general permit which

applies to all USAF bases. This general permit will then be modified into an individual permits by the state EPA in which each base resides. The EPA is not required to establish permit requirements until October 1993. These requirements may apply to any or all of the storm water pollutants discussed below.

Pollutants

Industrial pollutants are generated from a variety of daily activities at an airfield. Discharge levels must meet EPA standards in order to maintain water quality at a level that adequately protects public health. Some of the activities include:

- Aircraft and ground vehicle washing and cleaning,
- Fueling operations,
- Aircraft maintenance and repair work,
- Engine test cell operations,
- De/anti-icing operations of aircraft and pavements, and
- Ground vehicle maintenance. (DoT, 1991,:1)

The pollutants generated from these activities may be discharged for treatment to on-site airport treatment systems or to an off-site publicly owned treatment works (POTW). These wastes are "more difficult to treat than sanitary (domestic) sewage and represent a potentially significant threat to surface and ground water quality" (DoT, 1991:1).

EPA's NPDES regulations for storm water discharges specifically identify airport de/anti-icing operations as sources of storm water pollution. Airports with over 50,000 flights per year must monitor various parameters. These parameters include:

- Oil and grease,
- Biological Oxygen Demand (BOD_5), defined as the amount of oxygen consumed during microbial degradation of organics after five days,
- Chemical Oxygen Demand (COD), defined as the oxygen equivalent of organic matter that can be oxidized using a strong chemical oxidizing agent,
- Total Suspended Solids (TSS), defined as the portion of total solids that can be removed by a membrane filter with a pore size of 1.2 micrometers,
- pH, and
- Glycols and urea, the primary ingredients used in de/anti-icing materials. (US Congress, 1992:41249; D'Itri, 1991:326; Peavy and others, 1985:15, 39; Masters, 1991:108)

As stated earlier, the 1978-1983 Nationwide Urban Runoff Program (NURP) investigated the extent to which urban runoff was causing water quality problems. NURP's principal conclusions were:

1. Heavy metals are the most prevalent priority pollutant. Concentrations far exceeded EPA ambient water quality standards.

2. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA criteria.

3. Total suspended solids are fairly high in comparison with treatment plant discharges. (Walesh, 1989:70-71)

A 1984 EPA study also identified other pollutants that may contaminate surface waters, such as:

> ...heavy metals and inorganic chemicals (including copper, lead, zinc, and cyanide) arising from transportation activities. Petroleum products from spills and leaks are [also] important contaminants [that] may affect surface water. (US EPA, 1984:2-32).

Water Quality Impacts. Water quality impacts can be attributed to many nonpoint pollutants. Some of these impacts include toxic, organic, nutrient, pathogenic, sediment, radiological, and aesthetic degradation problems (Walesh, 1989:218). Table 1 below is a list of possible pollutants and their associated water quality impacts as identified in an EPA Report to Congress.

A Department of Transportation (DoT) report, titled Management of Airport Industrial Waste, also identifies other pollutants at an airfield.

Acids and Alkalies. These wastes can be generated during cleaning operations. They can corrode metal and concrete sewer pipes. They also interfere with sludge digestion and biological activity in waste water treatment systems and are toxic to fish. Normal water pH should range between 6.0 and 9.0. Acids and alkalies may lead to pH levels outside this range. (DoT, 1991:5).

TABLE 1

WATER QUALITY IMPACTS FROM NONPOINT POLLUTANTS

POLLUTANTS	WATER QUALITY IMPACTS
Sediments	- Decrease the transmission of light through water - Direct respiration and digestion effects on aquatic life - Decrease in viability of aquatic life - Increase in temperature of surface layer of water - Decrease in value for recreational and commercial activity - Increase in drinking water costs - Examples include sand, silt, clay and organic materials
Salts	- Destruction of habit and food source plants for fish species - Reduced suitability for recreation through higher salinity levels (skin/eyes irritation) and higher evaporation rates - Affect quality of drinking water
Pesticides/Herbicides	- Hinder photosynthesis in aquatic plants - Lower organism's resistance and increase susceptibility to other environmental stressors - Can kill non-target species - Can bio-accumulate in tissues of fish and other species - Some are carcinogenic and mutagenic and/or teratogenic - Reduce commercial/sport fishing and other recreational activities - Health hazard from human consumption of contaminated fish/water
Nutrients - Phosphorous - Nitrogen	- Eutrophication, or "promotion of premature aging of lakes and estuaries" - Nitrates can cause infant health problems - Reduced oxygen levels can suffocate fish species - Interference with boating and fishing activities - Eliminate submerged aquatic vegetation and destroy habitat and food source for aquatic animals and waterfowl
Metals	- Accumulate in bottom sediments, posing risk to bottom-feeding organisms - Bio-accumulate in animal tissues - Affect life spans and reproduction rates of aquatic species - Affect water supplies and recreational and commercial fishing
Bacteria	- Introduce of pathogens (disease-bearing organisms) to surface waters - Reduce recreational uses - Increase treatment costs for drinking water - Human health hazard (US EPA, 1984:1-10,1-11)

Organic Solvents and Phenols. These wastes are generated during the cleaning of aircraft and ground vehicles. They can create explosion and toxicity hazards and pollute potable water. Solvents and phenols, in particular, produce objectionable tastes and odors in water supplies. Solvents are also known to interfere with sewage treatment, primarily the bacterial activity in sludge digestion. The concentration of phenols in water, as specified in ambient water quality criteria for protection of human health, is 3.5 parts per million (ppm) (DoT, 1991:6). The maximum contaminant levels of several common industrial solvents, as specified in the Safe Drinking Water Act, are: .002 ppm for vinyl chloride, .005 ppm for carbon tetrachloride, .005 ppm for 1,2-dichloroethane, and .005 ppm for trichloroethylene (US Congress, 1991:671).

Oil, Grease, and/or Detergents. These wastes are generated during cleaning of aircraft and ground vehicles and in vehicle maintenance shop operations. Oil and grease layers will increase the BOD and interfere with the efficiency of the precipitant used for flocculation and coagulation in water treatment systems. The mixing of dirt with detergents also increases emulsions, which may clog small openings in water and waste water treatment units unless screened out. The pH of detergents, which usually ranges from 9.0 to 10.8, should be lowered before treatment because it can cause partial sludge flotation through the release of carbon dioxide (DoT, 1991:6).

De/anti-icing Chemical Wastes. Airports impact the environment through the use of wintertime de/anti-icing chemicals that contain glycols and urea. The chemicals are applied to aircraft and pavements, although "aircraft de/anti-icing operations generate more waste than pavement de/anti-icing activities" (DoT, 1991:6). If the storm water runoff from aircraft deicing operations is not adequately treated or contained, substantial amounts of deicer chemicals may be released to the environment. Of particular concern are the aquatic

toxicity of ammonia from urea degradation, oxygen depletion in receiving waters due to increased BOD loading, organic enrichment of receiving waters, and obnoxious odors that evolve from biodegradation processes (D'Itri, 1992:330). Ethylene glycol, a major component of most deicing and some anti-icing agents, is classified as a hazardous substance under U.S. law. Technically, any release of one pound of the substance must be reported to U.S. and state environmental agencies. Airports hope to avoid this by convincing environmental officials that use of de/anti-icing fluids are "well-planned, controlled releases that pose little threat to the environment" (McKenna, 1993b:44).

Pollutant identification can be a complicated and expensive process but it is a necessary step in deciding what BMPs should be implemented to meet NPDES storm water discharge permits. The next section discusses BMPs that may be implemented at AF installations.

<u>Best Management Practices</u>

Once a facility has identified and assessed potential and existing sources of storm water contamination, the next step is to select the proper measures to eliminate or reduce these pollutant discharges. According to the pollution prevention hierarchy, management practices and control technologies should be judged on their effectiveness to reduce pollution at the source, recycle contaminants in an environmentally safe manner, and treat pollutants to render them harmless (Aldrich, 1993:112). Generally, the practices that reduce runoff volume and pollution generation are substantially cheaper than end-of-pipe final treatment and removal (Novotny and others, 1989:61). The problem with storm water management planning is finding the best combination of structural, low-structural and nonstructural measures and integrating them into an effective whole (Walesh, 1989:391).

BMPs are defined by the Virginia Water Resources Research Center as:

> Practices that are determined to be the most effective and practicable (including technological, economic, and institutional considerations) means of controlling point and nonpoint pollutants at levels compatible with environmental quality goals. (Heatwole and others, 1991:1)

BMPs are used to prevent or reduce the amount of pollution from any type of activity. They are a very broad in nature and may take the form of a process, activity, or physical structure. Some BMPs are "simple and may be put into place immediately, while others are more complicated and require extensive planning and space" (US EPA, 1992c, 1-4). The selection of the appropriate BMP is important because of the varying nature of every location. Some may be suitable for one situation and inappropriate for another. The following should be considered when selecting which BMP to implement:

- Type of land-activity.
- Physical conditions in the watershed.
- Pollutants to be controlled.
- Site-specific conditions. (Novotny and Chesters, 1981:438)

In essence, though, BMPs are anything that a:

> ...plant manager, department foreman, environmental specialist, consultant or employee may identify as a method, short of actual treatment, to curb water pollution. (US EPA, 1992c:2-21)

BMPs can be divided into two subcategories of source controls: nonstructural and low-structural. These controls will now be discussed as they apply to storm water runoff.

Nonstructural. Nonstructural controls usually involve "little or no construction and typically require small-to-moderate capital investments" (Walesh, 1989:392). They are often the least costly BMPs to implement because they only involve modifying existing maintenance operations or enforcing ordinances that control development and planning practices (Finnemore, 1982: 110C). The most common nonstructural measures are good housekeeping, pollution prevention, land-use planning, and street sweeping.

Good Housekeeping. This measure, also classified as an institutional approach, requires the "maintenance of areas which may

contribute to storm water discharges in a clean, orderly manner" (US EPA, 1992c:2-23). Many times a little common sense and attention to details can result in less waste being generated. Some simple procedures to promote good housekeeping include:

- Improved operation and maintenance of machinery and processes,
- Material storage practices,
- Material inventory controls,
- Routine and regular clean-up schedules,
- Maintaining well organized work areas, and
- Educational programs for employees. (US EPA, 1992c:2-23)

"Institutional control agencies" can also be organized to ensure good housekeeping measures are practiced. They are organized to "adopt and enforce ordinances, conduct area-wide control projects, and levy stable and equitable sources of funding" (Finnemore and Lynard, 1982, 1100). This allocation of funds is important because limited budgets and manpower can often times prevent the implementation of these BMPs. Federal incentives that enable these institutional controls to be implemented may be necessary.

Pollution Prevention. The purpose of pollution prevention is to eliminate or reduce to as near zero as possible the release of waste to the environment. By order of the Secretary of the Air Force, the Air Force will:

> ...prevent at the source, to the greatest extent possible, environmentally harmful discharges to the air, land, surface water, and ground water. Wastes that cannot be prevented at the source will be recycled. Wastes that cannot be recycled will be treated in an environmentally sound manner. Waste disposal or releases to the environment are only permitted after all other pollution prevention alternatives have been exhausted. (Dept. of the AF, 1992:1.2)

The Air Force is currently evaluating the applicability and feasibility of storm water discharge pollution prevention. Research has focused on de/anti-icing operations. The following pollution prevention measures hold considerable promise:

1. Material substitution - The principal runway deicing chemical alternatives that may be used in lieu of urea and glycol include potassium acetate, calcium magnesium acetate, and sodium formate. Acetate-based deicers have the advantage of alleviating the threat of

ammonia, nitrate, glycol and 1,4-dioxane to the environment in the storm water runoff (D'Itri, 1992:336). Potassium acetate chemicals, such as BP Clearway I and Crytech E36, are "safer and their use is on the rise" (HQ AFCESA, 1993). An example of being environmentally safer is that the BOD_5 is only .27 grams oxygen/gram (versus .83 gm O_2/gm for propylene glycol). Potassium acetate is also functional at much lower temperatures, does not evaporate, and remains on the pavement longer (Mason, 1993; Gibbs and Willing, 1992:28). Calcium magnesium acetate (CMA) and sodium formate both have been accepted by the Federal Aviation Administration (FAA) as suitable runway de/anti-icers, while potassium acetate is still awaiting approval. Currently, there are no aircraft deicing alternatives "readily available or suitable to warrant the replacement of ethylene and propylene glycol chemical mixtures" (Gibbs and Willing, 1992:27).

2. Process changes - Centralized deicing may be used to deice aircraft. Operating a centralized facility on taxiways "would improve safety by deicing aircraft closer to the operating runway. It also would make it easier for airport officials to capture used fluids and prevent them from entering the environment" (McKenna, 1993c:43). When used in conjunction with a collection system, the deicing chemicals can be captured and recycled on or off site. This also leads to the possibility of re-using the recycled deicing chemicals (Gibbs and Willing, 1992:31).

Runway Ice Detection Systems (RIDS) is another process that may be used to help determine when to deice aircraft based on actual temperatures of both runways and aircraft. RIDS uses real-time weather forecasts in combination with sensor data to create a pavement temperature forecast. Flush-mounted sensors, along with central processing units and a software package, monitor actual surface temperature, precipitation and icing conditions. This can be critical "since the pavement temperature can vary from the ambient temperature by

as much as 20 to 30 degrees Fahrenheit" (Gibbs and Willing, 1992:29; HQ AFCESA, 1992). This information also helps in the implementation of anti-icing measures, "which require only a fraction of the chemical required for deicing" (HQ AFCESA, 1993).

Other processes are also being developed, primarily new sensors to detect ice and other forms of contamination on wings and other lifting surfaces during ground operations so that pilots will know when it is safe to take off. Some of these systems also include the use of infrared, ultrasonic, video, laser, and microwave observation technologies (Hughes, 1993:41).

Pollution prevention does not only encompass de/anti-icing materials. Progress is being made at airports to ensure that maintenance personnel receive the proper training and education regarding storm water pollution. Cleanup practices that incorporate absorbent pads, drip pans and sand are also being implemented for fuel spills/oil leaks in aircraft and maintenance areas (Backer, 1993; Jahangari, 1993).

Land-Use Planning. The goal of land-use planning is to "limit activities with high pollutant yields to areas of development than can support the intended activity and to protect the receiving waters" (Finnemore and Lynard, 1982:1101). Proper planning is usually the first step in preventing runoff problems during and after development, although implementing BMPs as developments are planned and constructed is usually more feasible and cost-effective than after development is complete (Reents and others, 1991:582). Since most AF bases are already developed, land-use planning may be difficult because "the range of available non-structural options decreases as development proceeds" (US EPA, 1992a:33).

The approach to land-use planning should consider the following elements:

- Physical characteristics of the site,
- Public needs and interests,

- Costs and profitability, and
- Regulatory requirements of environmental control agencies. (Finnemore and Lynard, 1982:1101)

These elements are necessary in order to balance the economic impacts of planned development with its potential environmental benefits.

Street Sweeping. Sweeping with brooms, squeegees, or other mechanical devices to remove small quantities of dry chemicals and dry solids can effectively control street-originating pollutants, most notably heavy metals (US EPA, 1992c:4-29). Two elements that should be considered when deciding to implement street sweeping are the cleaning interval and the efficiency of removing the pollutants. Street sweeping is moderately effective in controlling oil and grease, flotables, and salts, although it is "less effective in controlling sediments, nutrients, and oxygen-demanding matter" (Finnemore and Lynard, 1982:1101; US EPA, 1984:A-9). Street sweeping should be selected and tailored to specific problems, not every problem that comes along.

Low-structural. These controls use "natural land features with minor modifications, and small, simple structures such as earthworks and outlet devices" (Finnemore, 1982:836). They are applied at the source or upland areas of a watershed and control runoff in new developments or mitigate existing problems in developed areas (Finnemore and Lynard, 1982:1102).

Examples of typical low-structural controls are soil protection and stabilization, berms and protective dikes, temporary storage basins, detention ponds, percolation ponds and other pervious areas and porous pavements. Further discussion of low-structural controls occurs in the next section of this chapter.

Structural. Available treatment technologies are broadly categorized as structural measures, which can be defined as:

> ...major public works projects and as such require moderate to major planning and design efforts, formal approval by one or more government units or agencies, letting of construction contracts, and moderate-to-large capital investments and operation and maintenance commitments. (Walesh, 1989:392)

Structural measures are also "end-of-pipe facilities designed to control volume and pollution from storm water" (Finnemore and Lynard, 1982:1099). Examples of structural measures that are used to control storm water runoff are: infiltration systems, detention systems, and flow-through treatment facilities.

Infiltration Systems. The principle of infiltration systems as it applies to storm water is to divert the first wash-off of surface runoff through a filter media with subsequent discharge to either the surface or groundwater system. Systems are designed to capture the first 0.5 to 1.0 inches of runoff. Permeable soil and a low water table are prerequisites to any infiltration system (Walesh, 1989:416).

Infiltration systems allow storm water to infiltrate or percolate into the soil. The most commonly used infiltration systems include grass swales, infiltration basins, infiltration trenches, and porous pavement (Urbonas and Stahre, 1993:14). The advantages of these systems include:

- Reduction in pollutants to receiving waters
- Recharge of groundwater
- Reduction in sink hole formation from groundwater depletion
- Preservation and/or enhancement of local vegetation
- Reduction of flood peaks
- Smaller storm sewers
- Reduction of basement flooding in combined sewer system

Some of the disadvantage of infiltration systems include:

- Systems may be too large to be effective for large paved areas
- Soils may seal with time
- Infiltration systems need routine maintenance
- If system fails, large capital costs required to repair or construct new systems
- Groundwater levels may rise enough to cause basement flooding and/or damage to building foundations
- Possible contamination of underlying soil from infiltrated pollutants

As in any storm water management project, the use of infiltration systems must be assessed on a case by case basis (Urbonas and Stahre, 1993:7-8). Pollutant removal in an infiltration system is achieved by diverting storm water runoff into the soil. Removal mechanisms involve sorption, precipitation, trapping, straining, and bacterial degradation

or transformation; these mechanisms are complex and depend on the solubility and chemistry of each pollutant and the surrounding soil (Schueler, 1987:6.8).

Many factors must also be considered before selecting an infiltration system. These factors include the local vegetation, soil type and condition, groundwater condition, and storm water quality. The vegetation should be dense, which allows for easier rainfall percolation and an increase in plant evapotranspiration. The soil should have high porosity and permeability. The groundwater level should not be near the surface and the infiltration system must be located near groundwater inflow regions (Urbonas and Stahre, 1993:8-11). If the height of the seasonally high water table extends to within four feet of the bottom of the infiltration system, the site may not be suitable for such a system. If the bedrock layer extends to within two to four feet of the infiltration system, the site is not feasible (Schueler, 1987: 2.7). Types of infiltration systems include swales, infiltrations basins and trenches, and porous pavement.

Swales. Swales are shallow grassed surface ditches that operate by storing runoff and allowing it to infiltrate; swales are usually incorporated in the site landscaping (Beale, 1992:144). See Figure 1 below. This BMP can be effective when properly installed on terrains with slopes less than 3.0% (Urbonas and Stahre, 1993:435). A 15 foot wide swale with a 3:1 sideslope will cost approximate $6.50 per linear foot; this price includes excavation/shaping plus seeding with a straw mulch cover (Schueler, 1987:9.5).

Removal rates for suspended solids by grass swales which have flow velocities less than 0.5 feet per second (fps) and underlying soils with high infiltration rates may be in excess of 80% (Urbonas and Stahre, 1993:435). In a study conducted on storm water in Durham, New Hampshire, the following pollutant removal efficiencies were reported: BOD at 11%, COD at 25%, suspended solids at 33%, nitrogen as NH_3 at 51%,

phosphorous at 5%, cadmium at 56%, copper at 48%, lead at 65%, and zinc at 51% (Oakland, 1983:184).

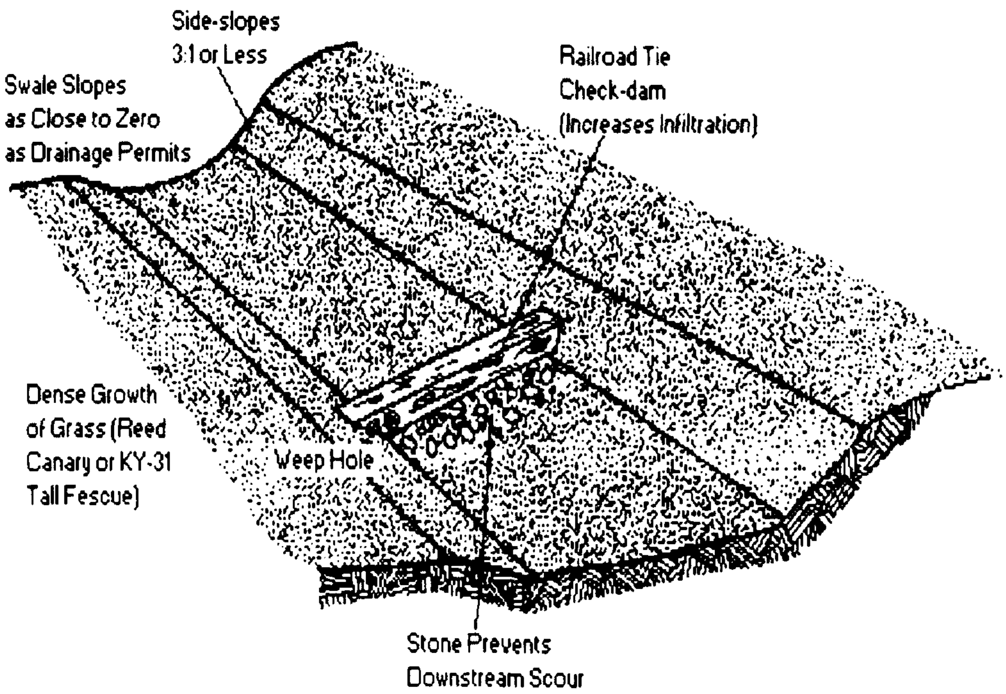


Figure 1. Schematic of a Grassed Swale
(Schueler, 1987:9.3)

Infiltration Basins. The infiltration basin is constructed by excavating a basin large enough to hold storm water discharges from the design storm. See Figure 2 below. The storm water enters the basin through overland flow and storm water piping. A well designed basin will allow for total storm water infiltration. Problems with these basins are that they tend to easily clog with sediment, may cause an unnatural rise in the groundwater table, and are not visually pleasing (Urbonas and Stahre, 1993:17-18). This system differs from the

infiltration trench in that it can serve a drainage area from 5 to 20 acres (Schueler, 1987:2.5).

A basin sized to store and infiltrate the runoff produced from the two year design storm has been shown to reduce sediments by 99%, total phosphorous by 65-75%, total nitrogen by 60-70%, metals by 95-99%, BOD by 90%, and bacteria by 98%. Smaller basins will have lower removal efficiencies (Schueler, 1987:6.8).

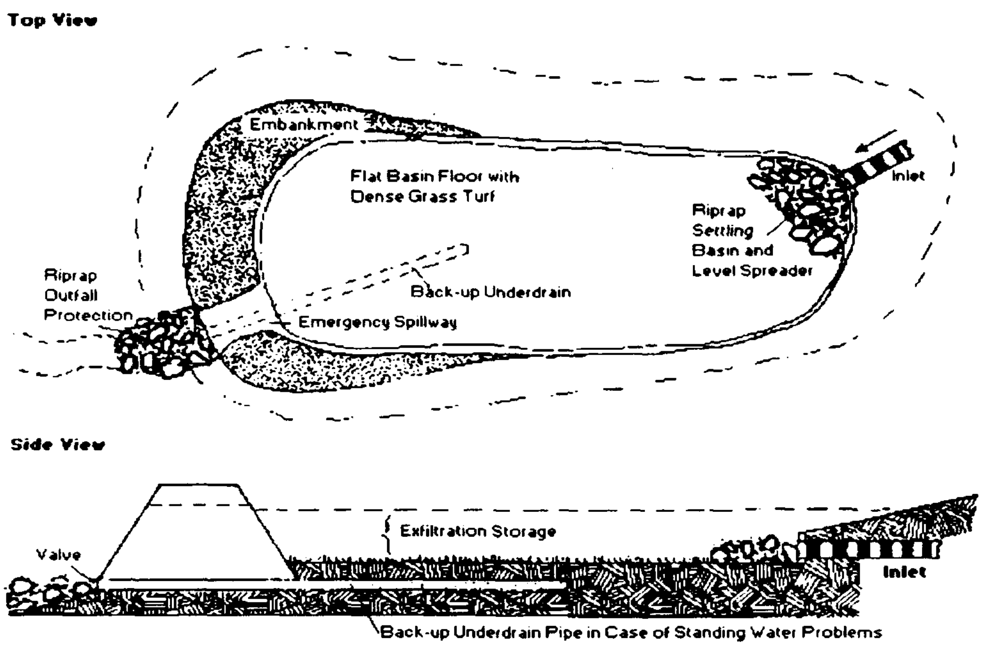


Figure 2. Schematic of an Infiltration Basin (Schueler, 1987:6.1)

<u>Infiltration Trenches</u>. The infiltration trench is constructed by excavating a pit, filling it with permeable fill (gravel or crushed rock), and backfilling over the permeable fill. See Figure 3. Storm water discharges can either be sent to the trench via storm

water piping or through overland flow. Storm water enters the trench and then percolates into the ground (Urbonas and Stahre, 1993:18). This system is not effective for large drainage areas; the maximum drainage area for this system should not exceed 5 acres (Schueler, 1987:2.5).

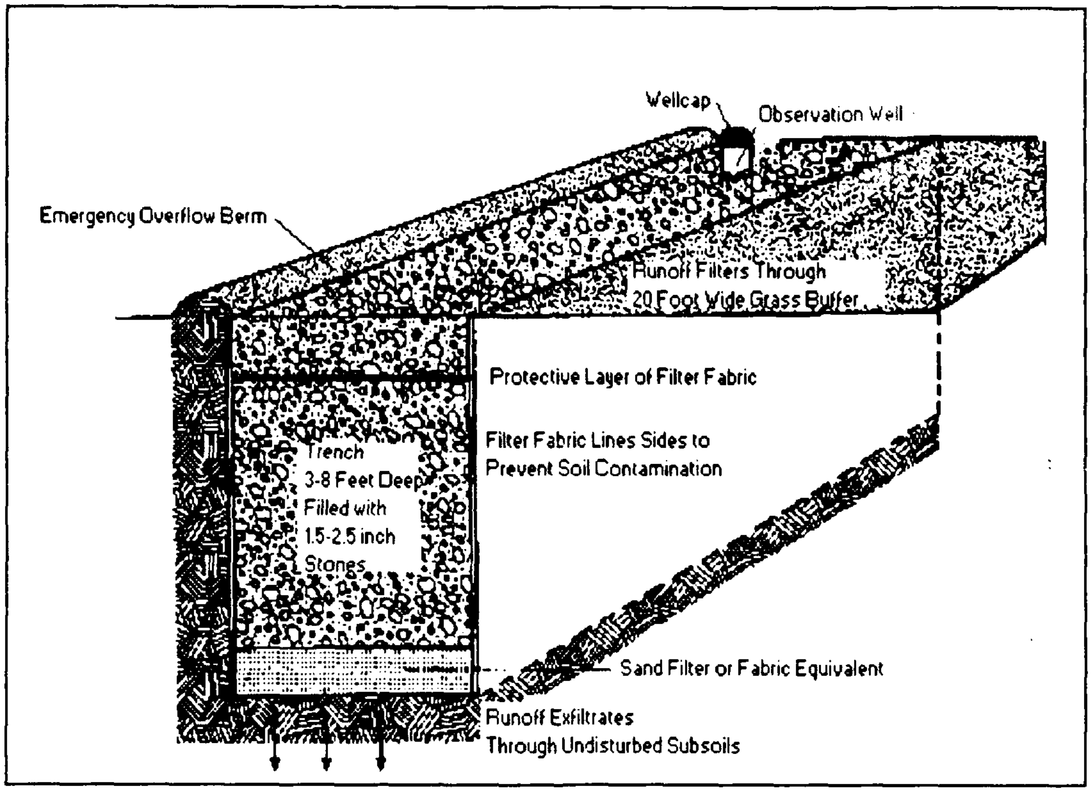


Figure 3. Schematic of an Infiltration Trench (Schueler, 1987:5.1)

<u>Filter Strips</u>. Filter strips are areas of vegetation adjacent to impervious areas. See Figure 4. Filter strips are similar to grass swales except they are only effective with overland laminar flow. Precautions must be taken to prevent the channelization of flow.

A filter strip must be equipped with a level spreading device to maintain laminar flow. A common level spreader is a stone trench between the impervious layer and the filter strip. Vegetation needs to

be dense and erosion resistant. The strips should also be as long as the impervious surface and should be low sloped.

Pollution removal effectiveness depends on the length and width of the strip, type of vegetation, slope and soil permeability, size of runoff area, and runoff velocity. The minimum width of the strip should be 20 feet, but strips in excess of 100 feet are required to remove smaller sized sediment. Small filter strips (around 20 feet) are similar to grass swales in regards to their pollutant removal effectiveness. Forested strips 100 feet wide with level spreaders have been shown to remove 80-100% of suspended solids, 40-60% of nitrogen and phosphorous, 60-80% of BOD and COD, and up to 100% of lead, zinc, and copper (Schueler, 1987:2.13,9.6-9.8).

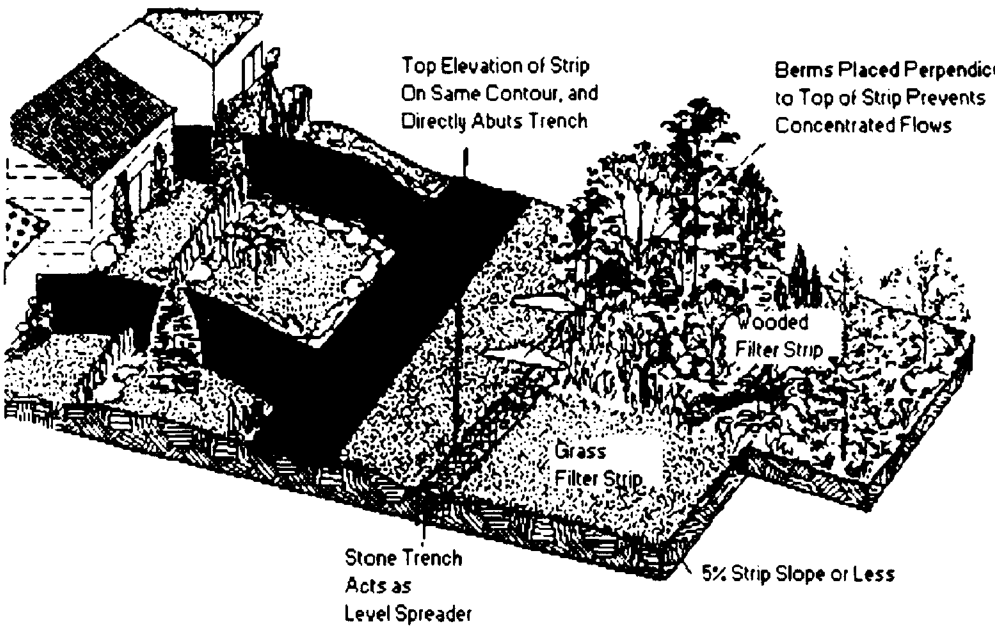


Figure 4. Schematic of a Filter Strip
(Schueler, 1987:9.10)

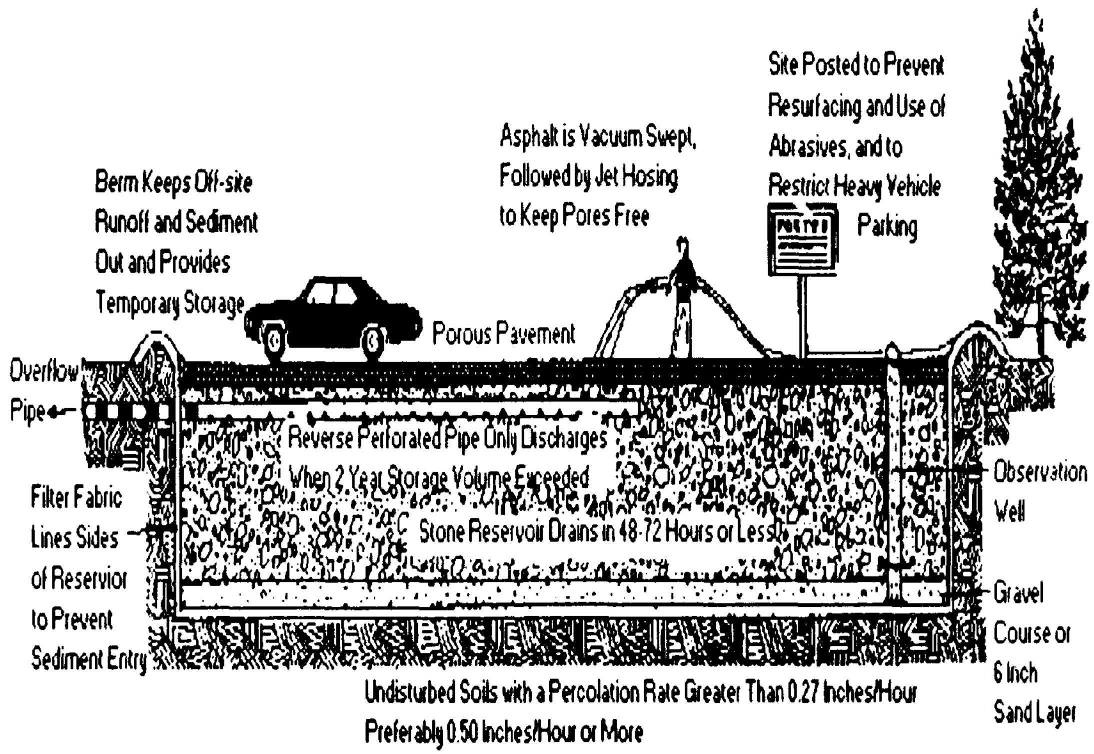


Figure 5. Schematic of Porous Pavement (Schueler, 1987:7.1)

Porous Paving. Porous paving increases infiltration which in turn decreases the amount of surface runoff. See Figure 5. The advantages of porous paving include a reduction in the total volume of surface runoff, reduction of the peaking effect of local floods, increased skid resistance, improved roadside vegetation, preservation of natural drainage patterns, and resistance to puddle formation. The disadvantages are that the filtering effectiveness of the pavement sub-base has not been established, pores may become clogged, and a special maintenance program is needed (URS, 1977:121). A study in Rochester, New York, indicated that peak runoff rates were reduced as much as 83% and the structural integrity of the porous pavements was not impaired by heavy loads or freezing (Novotny and others, 1989:61). Unfortunately, porous pavement is currently not acceptable for use on USAF airfield pavements due to structural integrity questions.

Injection Wells. This method requires the injection of storm water from a catchment basin under pressure into the groundwater strata. The water that is injected must be similar or better in quality than the in-situ groundwater. An advantage of pressure injection is a decrease in storm water discharges. Also, the same well can be used for injection and extraction. Major disadvantages are the expense and operation of injection wells and the probability of contaminating the groundwater (URS, 1977:153).

Detention Systems. Detention facilities temporarily detain storm water runoff. These systems are primarily used to reduce the peak flow rate of storm water discharges and remove sediments in order to improve storm water quality. Detention facilities should be designed to have sufficient volume to control discharges of the design storm. In some jurisdictions the detention facility must be designed to control the 100 year storm while other jurisdictions only require the 2 year storm (Urbonas and Stahre, 1993:256). Types of detention systems are discussed below.

Sedimentation Basins. Gravity separation of suspended materials from aqueous solutions is the oldest and most widely used process in water treatment. Suspensions that are heavier than water, given an adequate detention time, will settle out as a result of gravitational forces. Detention times are dependent on the type of particle being removed; the heavier the particle the shorter the detention time. If a particle has a similar density to that of water, detention time for gravity settling will be long (Montgomery, 1985:135-137). Sedimentation basins are commonly constructed with concrete and, therefore, are not used as much as the more naturally appearing detention/retention ponds discussed below.

Parameters which affect sedimentation process design are: nature of the suspended matter, settling velocity, local climatic conditions, flow rate, land space available, and overall configuration of the settling basin (Kawamura, 1991:129).

Detention/Retention Ponds. Detention/retention ponds detain runoff in order to reduce the maximum discharge rate of runoff and/or provide significant detention time to improve storm water quality through natural physical, chemical, and biological processes. See Figures 6 and 7. Detention/retention ponds are similar to sedimentation basins except the ponds are designed to enhance the beauty of the landscape. Advantages of the ponds include the sedimentation of suspended solids of more than 10 microns in diameter, possible recreational value, and possible reduction in size of storm drainage structures due to decreases in the discharge flow (URS, 1977:147). Detention ponds are designed to capture storm water and slowly discharge the water over a designed period; once the design period is over (commonly 36 hours), the detention pond is completely emptied out. Retention ponds are similar to detention ponds, but they are designed to always store a designated quantity of water indefinitely. Thus, detention ponds are sometimes referred to as dry ponds and retention

ponds are referred to as wet ponds. Since a retention pond retains a certain quantity of water, it usually produces higher quality water due to the additional effects of biodegradation of the storm water pollutants. Because of this, and the fact that retention ponds are more aesthetically pleasing, retention ponds are the preferred option in many cases (Urbonas and Stahre, 1993:436-37).

A detention/retention pond that provides a mean detention time of 18 hours may be adequate to settle out 60% of total suspended solids, leads, and hydrocarbons and 45% of the total biochemical oxygen demand, copper, and phosphates from urban storm runoff (Akan, 1992:381).

It is not sufficient to only address hydrology and hydraulics when planning a detention pond. The planning must also consider the social, environmental, safety, and recreational needs of the community (Urbonas and Stahre, 1993: 39-40). Detention ponds have been shown to effectively decrease pollutant concentrations, but they may cause water quality degradation if not properly designed. Problems may include the following:

- Nutrient enrichment resulting in accelerated eutrophication. Excessive algae levels can deplete oxygen and cause fish kills;
- Deposits of sedimentation containing heavy metals and attached petroleum product will occur in the bottom silt;
- De-icing chemicals may increase lake salinity;
- Surface runoff may increase the acidity of the water (Urbonas and Stahre, 1993:42-43).

Based on field studies from a number of sources, a properly designed extended detention basin (detains water for at least 36 hours) can be expected to achieve the following pollutant removal rates:

TSS:	50-70%
TP:	10-20%
Nitrogen:	10-20%
Organic Matter:	20-40%
Lead:	75-90%
Zinc:	30-60%
Hydrocarbons:	50-70%
Bacteria:	50-90%

Retention ponds do not empty out entirely and have been shown to produce water of higher quality than detention ponds; they reduce phosphorous by an additional 30-40% and total nitrogen by 20% (Urbonas and Stahre, 1993:363,437).

Wetlands. Wetlands are another method to detain/retain storm water. Wetlands are an "ecotone"--an edge habitat, a transition between dry land and deep water, an environment that is neither clearly terrestrial nor clearly aquatic (Hammer and Bastian, 1990:5). See Figure 8 below. The U.S. Fish and Wildlife service recognizes wetlands as:

> ...a transition between terrestrial and aquatic systems, where water is the dominant factor determining development of soils and associated biological communities and where, at least periodically, the water table is at or near the surface, or the land is covered by shallow waters. Specifically, it requires that wetlands meet one or more of three conditions:
>
> 1. Areas supporting predominantly hydrophytes (at least periodically),
> 2. Areas with predominantly undrained hydric soil (wet enough or long enough to produce anaerobic conditions that limit the types of plants that can grow there), and/or
> 3. Areas with non-soil substrate (such as rock or gravel) that are saturated or covered by shallow water at some time during the growing season. (Hammer and Bastian, 1990:5-6)

Wetlands are an essential part of nature's storm water management system. Important wetland functions include conveyance and storage of storm water, reduction of flood flows and erosion, increased sedimentation, and modification of pollutants through natural mechanisms. Constructed artificial wetlands can be designed to meet specific treatment requirements while providing new wetland areas that also improve available wildlife habitats. Management of natural marshes, swamps and bogs has been shown to reduce and neutralize nutrients, heavy metals, organics, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), fecal coliforms, and pathogenic bacteria (Martin and Martin, 1991:101).

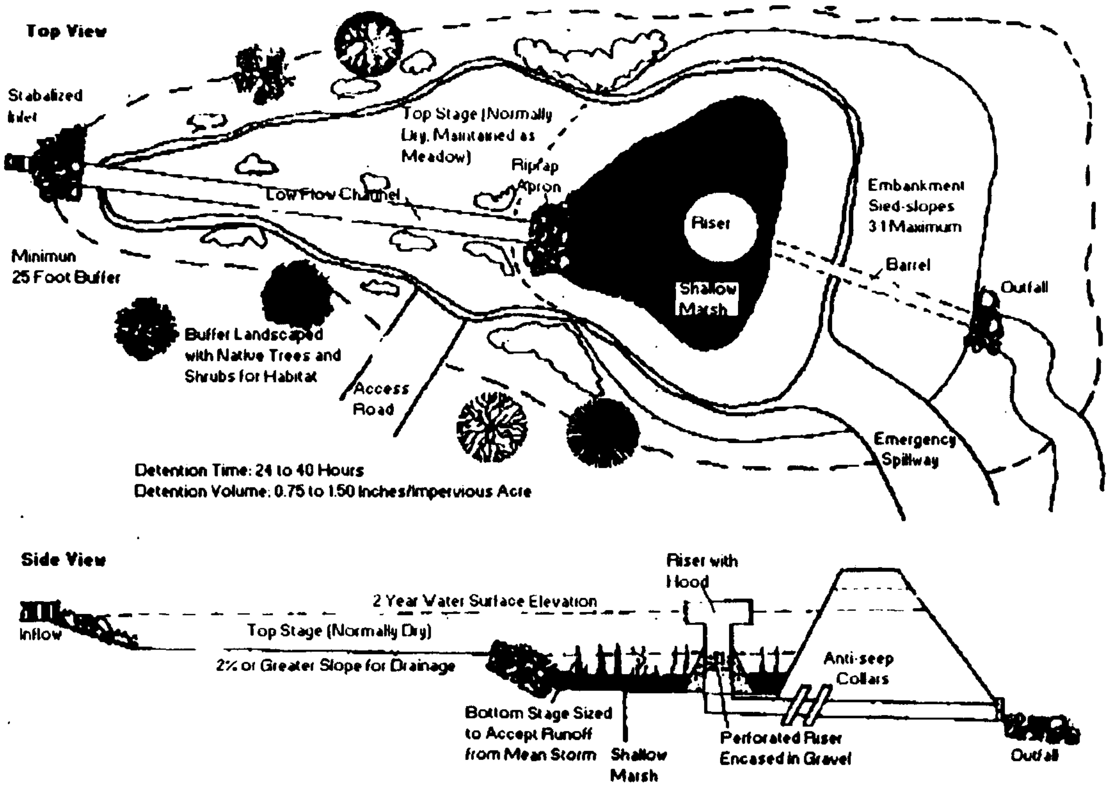


Figure 6. Schematic of a Detention Pond (Schueler, 1987:3.29)

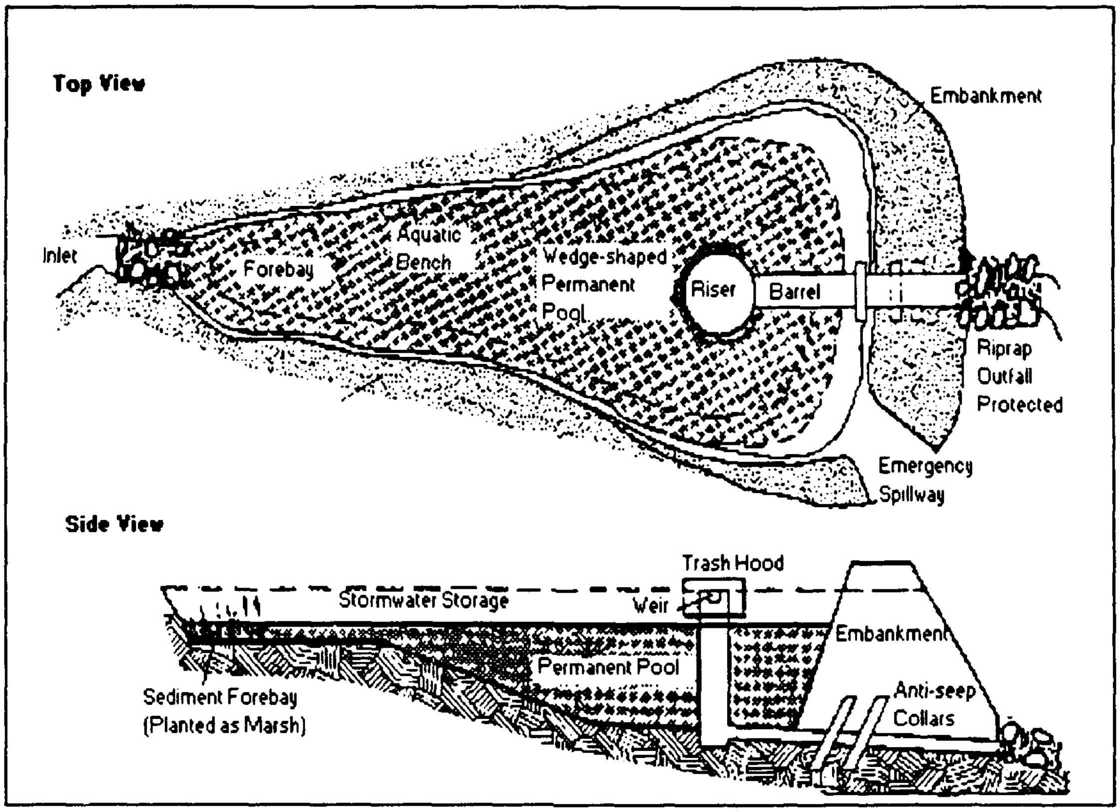


Figure 7. Schematic of a Retention Pond (Schueler, 1987:4.20)

In test units and constructed artificial marsh facilities using various waste waters, the following removal percentages were reported: BOD_5: 80 to 95%; TSS: 29-87%; COD: 43-87%; nitrogen: 42-94%; total phosphate: 94%, coliforms: 86-99%; heavy metals were highly variable depending on the type of pollutant (Martin and Martin, 1991:101). Based on this data, wetlands appear to effectively control storm water pollution.

A major concern of using wetlands for storm water pollution control is that little scientific information is available on the short- or long-term pollutant effects on wetlands, their natural functions, or associated fauna (Hammer and Bastian, 1990:253).

Extended contact with biological media found in wetlands is extremely important in the wetland's ability to remove dissolved

pollutants. The use of wetlands for storm water treatment is currently evolving. Some factors that affect their successful implementation are the geographic, climatic, and meteorologic conditions, along with the nature of the storm water that needs treatment (Urbonas and Stahre, 1993: 383).

The efficiency of wetlands in removing nutrients found in storm water appears to vary among sites. Nutrient removal percentages range from an increase of 4% to a decrease of 62% of NH_3 and a 4% increase to a 90% decrease in total phosphorus (Urbonas and Stahre, 1993:384).

In a study conducted in the U.S. on several wetlands that were used to treat urban storm water, the average removal efficiencies of suspended solids was found to be 40-96% with an average of 87%. Lead removal ranged from 20-94% with an average of 85% (Urbonas and Stahre, 1993:384).

Another study on wetlands conducted by A.L. Goldstein observed that the efficiency of nutrient uptake from agricultural runoff in a Florida wetland decreased as the annual unit loading rate increased and the wetland aged over three years. This may suggest that the wetlands need to be cleaned out every few years to maintain an abundance of young highly productive plants in an early successional stage. Goldstein also reported the wetlands ability to remove nitrogen as "poor" and its ability to remove phosphorus ranged from 25-50% as long as the loading was less than 88 pounds/acre/year (Urbonas and Stahre,1993:384).

Flow-through Treatment Facilities. Flow through treatment facilities are systems that treat the storm water as it flows through the structure. Such systems include oil/water separators, water quality inlets, dissolved air flotation, and sand filters. These systems are discussed in greater detail below.

Oil/Water Separators. Oil, grease, and other substances lighter than water can rise to the surface where they form a floating surface layer and subsequently can be skimmed (Novotny and

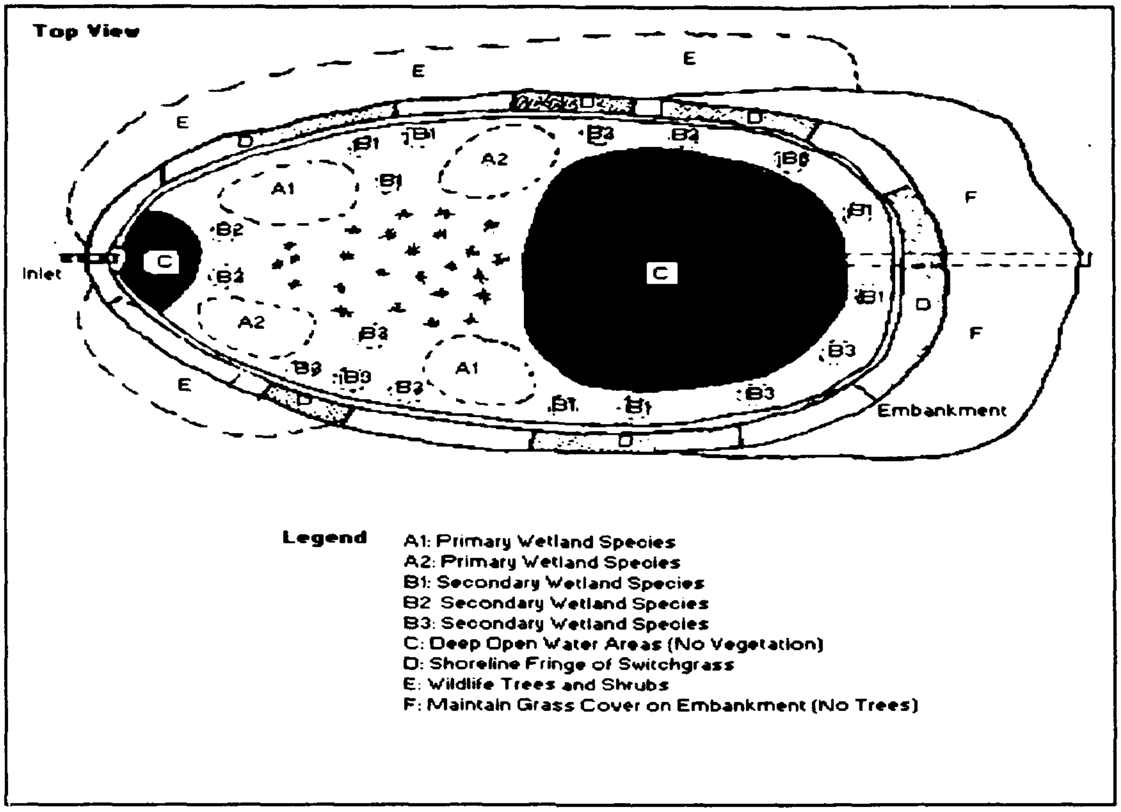


Figure 8. Schematic of a Constructed Wetland (Schueler, 1987:9.18)

others, 1989:111). Oil/water separators work based on the fact that oil and water have different densities; given a significant surface area and detention time, oil will float to the top of the water. A properly designed oil/water separator provides adequate surface area and detention time so the separation of oil and water will occur; water is then discharged from the separator below the oil and water boundary. Oil/water separators also require periodic maintenance for oil and grease removal (URS, 1977:253).

Water Quality Inlets. Floating debris cause both pollution and safety problems. Debris may clog culverts, reduce the aesthetic value of streams, and obstruct small water craft (URS, 1977:257). Water quality inlets serve as a means to prevent floating debris from entering the storm sewer system and may, to some degree,

function as an oil/water separator. See Figure 9. These inlets only store a small fraction of the two year design storm and therefore have little effect on peak design rates. Since runoff is briefly retained, only moderate removals of coarse sediments, oil/grease, and debris can be expected.

Water quality inlets typically serve parking lots one acre or less in size. Capital costs range from $6000-$20,000. Inlets should be cleaned a minimum of twice a year to remove collected materials.

The major advantage of the system is the removal of large debris before they enter the storm drainage system (Schueler, 1987:8.1-8.2).

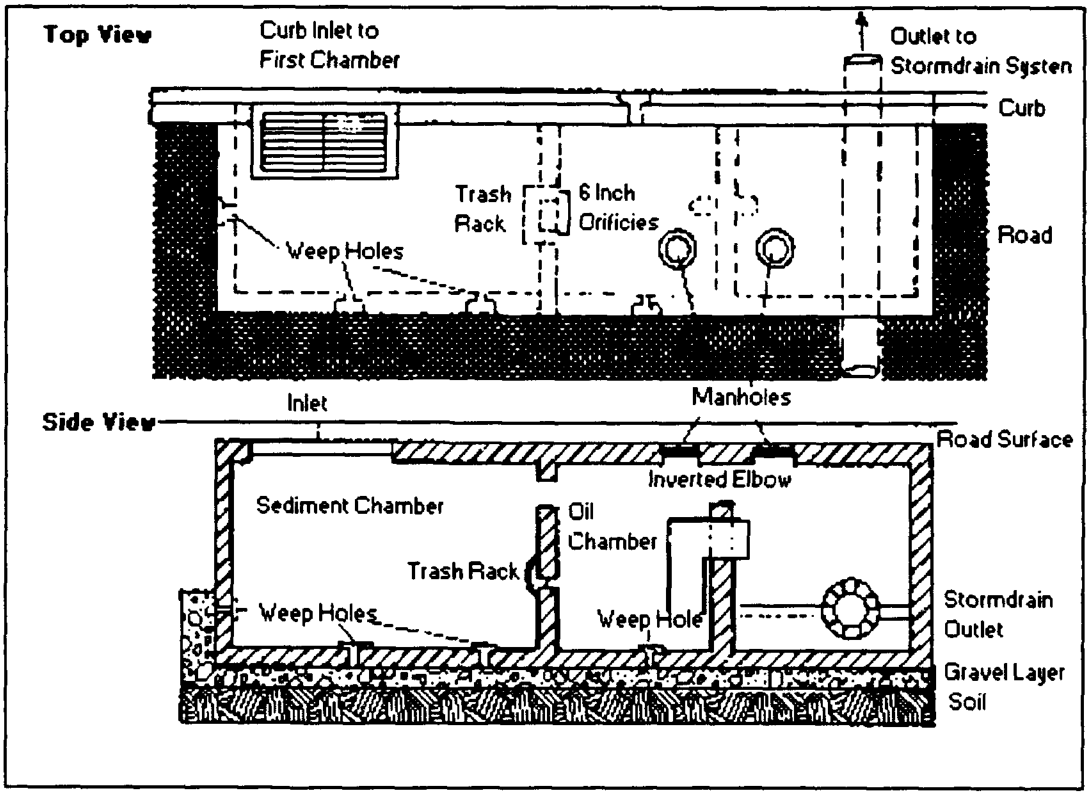


Figure 9. Schematic of a Water Quality Inlet
(Schueler 1987:8.3)

Dissolved Air Flotation. Dissolved air flotation (DAF) is similar to sedimentation except that light weight particles are

floated to the surface via micro-bubbles instead of settled by gravity. Flotation has several process advantages over sedimentation; it can produce better water quality and it can be operated at higher surface loadings, resulting in smaller plants. DAF has become accepted as an alternative to sedimentation in the United Kingdom and in Scandinavia (Zabel, 1985:42). DAF works by decreasing the apparent density of the solid. After saturating a portion or all of the feed water with air at a pressure of 40 to 50 psi, microscopic air bubbles are formed which attach to oil and suspended solids. The material floats to the surface and forms a froth that is skimmed off. Retention time ranges from 20 to 60 minutes. DAF should be considered when waste water contains industrial waste high in oil and grease (Martin and Martin, 1991:236). When used on storm water, DAF has been shown to remove 45-85% of suspended solids, 30-80% of BOD_5, 55% of COD, 55% of total phosphorus, and 35% of Kjeldahl Nitrogen. The capital cost for a DAF facility is estimated at $34,000 per million gallons of treatment capacity per day (Wanielista and Yousef, 1993:531).

<u>Slow Sand Filters</u>. A slow sand filter, which consists of a water tight box provided with an underdrain system, filters out contaminants. The effective size of the sand is from 0.15 mm to 0.35 mm in diameter. The sand is placed in the box to a depth of approximately 1.2 to 1.4 meters. Water is run through the sand at a rate of 2.5 to 6.0 m^3/m^2/day. A distinguishing feature of this filter is the presence of a "schmutzdecke"; a schmutzdecke is a thin layer of biologically active micro-organisms that breakdown organic matter and help retain other solid matter more effectively (Martin and Martin, 1991:21-22). A problem with slow sand filters is the raw water must not be too contaminated with suspended solids or else the filter will clog; generally, total suspended solids should not exceed 50 mg/l. Advantages include simplicity of design, no chemical or power requirements, and no need for backwash if contaminated sand is removed periodically (Martin

and Martin, 1991:23). Sand filters can be effective when land use is at a premium. However, filter beds, and especially filter inlets, can be expensive to construct and can require significant maintenance to keep in operating condition (Urbonas and Stahre, 1993:436). See Figure 10 below.

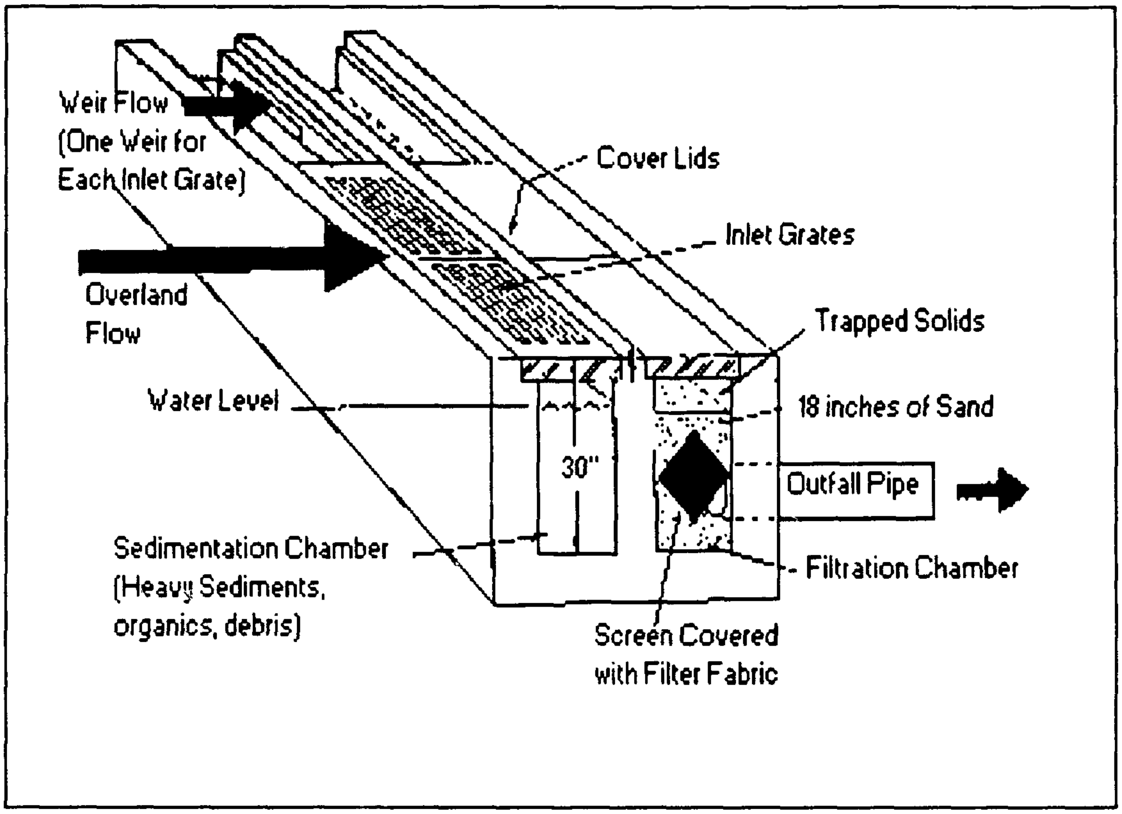


Figure 10. Schematic of a Sand Filter
(Urbonas and Stahre, 1993:421)

<u>Rapid sand filters</u>. Rapid sand filters work on relatively the same principle as slow sand filters except they work at higher flow rates and don't require the formation of the schmutzdecke. Rapid sand filters use a coarser sand placed above a gravel bed. The advantage of this form of filter is it can be used on very turbid waters. Major disadvantages of rapid sand filters are they require

backwashing, periodic downtime for maintenance, and cost more than slow sand filters (Martin and Martin, 1991:28).

The average removal efficiencies for sand filters were between 60% and 80% for suspended solids, biochemical oxygen demand, total phosphorous, total organic carbon, chemical oxygen demand, and dissolved zinc. A disadvantage of sand filters is that in some cases, dissolved solid concentrations of the effluent increased an average of 13% over the influent concentrations (Urbonas and Stahre, 1993:436).

Sand filters used for storm water is a relatively new idea and accurate construction cost data is not readily available (although one system built in Austin, Texas cost approximately $16,000 per acre of impervious watershed served). The surface layer needs to be cleaned out at least once a year and maintenance is required more frequently under frequent and/or severe storms. Yearly maintenance costs approximately equal $2,000 per 200 feet of filter trench (Urbonas and Stahre, 1993:421-22).

In areas where sand filter inlets are not practical, sand filter basins in conjunction with an extended detention facility have been effectively used, one example being in Aurora, Colorado. This type of system can effectively treat 200 acres of watershed. The surface area of the filter will equal the maximum release rate from the detention facility divided by the permissible loading rate on the filter; the design loading rate is usually 0.09 gallons per minute per square foot (gpm/ft^2). A filter of this size would cost approximately $100,000 to construct; this cost is based on a unit loading rate of 0.09 gpm/ft^2 of filter area and the filter being installed downstream of a detention basin that meters out the flow through a water quality inlet over a 36 hour period. See Figure 11 for a typical schematic of a sand filter downstream of a detention pond (Urbonas and Stahre, 1993:431).

<u>Future BMP Concerns</u>. In looking towards the future, more regulations are going to be imposed in order to protect the environment

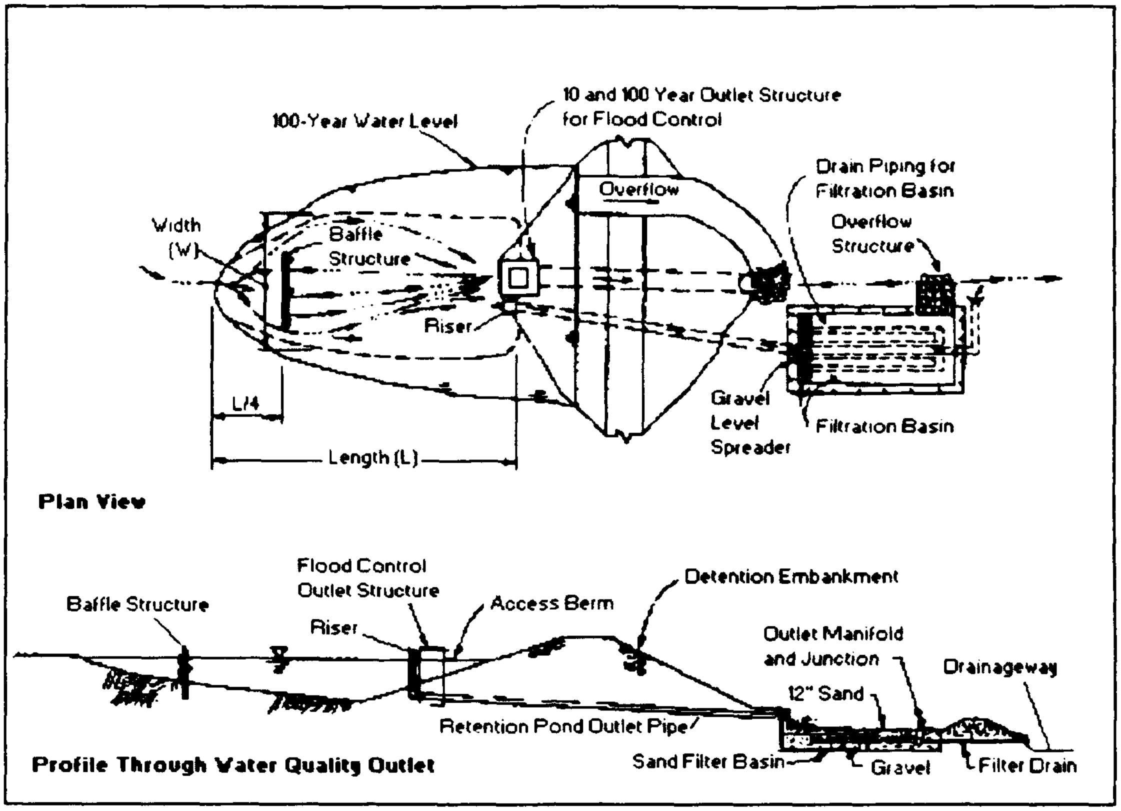


Figure 11. Schematic of a Sand Filter Downstream of a Detention Pond (Urbonas and Stahre, 1993:432)

and public from NPS pollution. As future water quality objectives are adopted and sufficient monitoring data is gathered to determine compliance, "selection and design of BMPs will change from using prescribed minimum standards to using actual performance criteria" (Reents and others, 1991:582). It is evident that BMPs designed to meet minimum standards today may not be sufficient to meet future water quality goals. In the meantime, it is important to implement BMPs since we are still responsible for our pollution. As quantitative goals are developed by the EPA, revision or upgrading of BMPs may be required. However, at least some level of control will already exist and the need for future additional controls will be reduced (Reents and others, 1991:583).

The structural BMPs discussed above can have very high capital and operating expenses. Treatment should only be used as a last resort to control storm water quality. A better method of achieving storm water quality goals is implementing an effective program of non-structural best management practices that prevent pollution and/or stop the migration of pollutants into the storm water.

Conclusion

This chapter discussed the available literature concerning storm water runoff. The regulations governing the control of storm water pollution are strict and complex. Many management practices exist to prevent and control nonpoint source pollution. The USAF must be prepared to make large capital expenditures and implement changes to its standard operating procedures if it expects to meet the requirements of future NPDES storm water permits.

III. Methodology

This chapter outlines the methodology that was employed to analyze storm water management practices that may assist Base Civil Engineers (BCEs)/Environmental Managers (EMs) in complying with National Pollutant Discharge Elimination System (NPDES) storm water discharge requirements for airfield pavements. The specific problem was subdivided into three investigative questions:

1. What are the applicable rules and regulations associated with storm water runoff at airfields?

2. What are the types and levels of storm water pollutants generated from airfield activities?

3. What management practices can be implemented at USAF airfields to ensure compliance with future NPDES storm water requirements?

Data Collection Procedures

The first investigative question was answered by conducting a literature review to obtain information on all applicable Air Force rules and regulations that govern storm water runoff. This literature, which primarily included Congressional legislation and U.S. Environmental Protection Agency regulations, provided an understanding of what must be accomplished to attain compliance with NPDES standards.

The second investigative question characterized storm water effluent from USAF installations. The EPA directed fifteen USAF installations to collect storm water samples for analysis. The results of these storm water samples were anticipated to be used as a basis for the characterization of USAF airfield storm water. Since the sampling of these bases is not complete, the storm water data was not available. Thus, the storm water information used identify the types and levels of pollutants was obtained from the American Association of Airport Executives' (AAAE) sampling report on airfield storm water quality.

Finally, to answer investigative question three, an extensive literature review was conducted on storm water effluent control

technologies and pollution prevention alternatives available to control the quantity and quality of storm water discharges. Some of the technologies that were investigated include constructed wetlands, dissolved air flotation, oil/water separators, filtration systems, detention/retention ponds, and sedimentation basins. Other technologies that have possible storm water applications were also discussed. To determine applicability for USAF implementation, construction and operating costs, manpower and operator expertise, land-use, equipment, and maintenance requirements were analyzed.

Data Analysis Procedures

The information gained on the various management practices was analyzed regarding their usefulness to USAF applications. Since treatment effectiveness varies among locations, a result of this thesis is a decision framework for choosing among various management practices that may be implemented to solve the storm water problem. This decision framework steps a BCE/EM through a series of charts that narrow the BMP options. The charts encompass parameters such as: watershed area, soil permeability, other restrictions on BMPs, storm water discharge control, pollutant removal effectiveness, community factors, and economic factors. Due to varying site conditions, the BCE/EM must assign weighting factors to the chart parameters to ensure the data from the decision support framework is relevant and appropriate.

As an end result, the BCE/EM will be able to use the information from this thesis to develop a base specific storm water management plan that will meet NPDES permit requirements.

IV. Results and Analysis

The purpose of this research is to analyze storm water best management practices to assist Base Civil Engineers (BCEs)/Environmental Managers (EMs) in complying with NPDES storm water discharge requirements for airfield pavements.

This chapter consists of an analysis of storm water data received from the American Association of Airport Executives (AAAE), United States Air Force (USAF) bases, and civilian airports to characterize USAF storm water. The pollutants in the waste stream are then evaluated in Chapter V to determine which best management practices (BMPs) are capable of treating/controlling the pollutants.

American Association of Airport Executives (AAAE) Survey

The results of the AAAE survey of storm water pollutants can be found in Tables 2 and 3 below. Because of confidentiality restrictions, the names of the civilian airports that conducted the grab and composite sampling could not be obtained. Table 2 lists the results of the grab samples, which must be obtained during the first 30 minutes of a discharge. Table 3 lists the results of the composite samples, which must be collected during the first 3 hours of discharge or the entire discharge if the discharge is less than 3 hours (US EPA, 1993:37). The data presented in these tables include the mean, standard deviation, maximum and minimum concentrations, and sample size (i.e. number of airports) for each pollutant.

TABLE 2

POLLUTANT CONCENTRATIONS AT CIVILIAN AIRPORTS (ppm)

GRAB SAMPLING

POLLUTANTS	MEAN	S.D	MAX	MIN	n
BOD_5	10.10	10.40	46.00	2.00	43
COD	58.00	59.00	352.00	5.00	42
P	0.39	0.46	2.22	0.02	38
N	0.77	1.08	4.26	0.02	39
TKN	1.80	2.80	16.50	0.22	40
TSS	55.00	101.00	478.00	1.00	39
O&G (.5 hrs)	3.67	4.22	24.00	1.00	66
O&G (1.5 hrs)	3.61	3.06	13.00	1.00	61

TABLE 3

POLLUTANT CONCENTRATIONS AT CIVILIAN AIRPORTS (ppm)

COMPOSITE SAMPLING

POLLUTANTS	MEAN	S.D	MAX	MIN	n
BOD_5	7.40	7.90	37.00	2.00	43
COD	51.00	39.00	182.00	5.00	42
P	0.28	0.23	0.91	0.03	39
N	0.48	0.43	1.65	0.02	40
TKN	1.08	1.26	7.81	0.04	42
TSS	50.00	92.00	450.00	2.00	40

BOD_5 - Biochemical oxygen demand after 5 days
COD - Chemical oxygen demand
P - Phosphorous
N - Nitrogen
TKN - Total Kjeldahl Nitrogen, which is a measure of organic and ammonia nitrogen and is a good indicator of nitrogen loading levels (Praner and Sprewell, 1992:25,159)
TSS - Total suspended solids
O&G - Oil and grease after .5 and 1.5 hours

The data from the AAAE survey was based on sampling reports from 59 airports throughout the country. The responding airports were found to represent good geographic coverage and a full range of annual operations. AAAE believed that a large enough response rate was obtained to provide enough information on the characterization of storm water runoff at nationwide airports (AAAE, 1993:1).

The 59 surveyed airports also indicated the types of management practices they were implementing to control/prevent storm water pollution. These include:

- 3 are designing future projects for "zero discharge"
- 8 are using sweeper trucks (without vacuums) to move debris of the taxiways and runways
- 22 are using detention ponds, oil/water separators, or other containment measures
- 19 are currently writing their Spill Prevention Plans to include effects on storm water runoff

United State Air Force/Civilian Airports NPDES Limits

NPDES storm water permits from various civilian and Air Force installations were obtained in order to determine what the typical grab sample daily maximum limits are for storm water discharges. Based on this survey, it appears on the average that an airfield/airport may be held accountable for the discharge limits shown in Table 4 below. Also included in Table 4 are the actual grab sample concentrations measured at the various facilities to allow a comparison between regulatory limits and actual concentrations. Grab sample measurements were used instead of composite measurements because it is sometimes important to design the treatment facilities where "first-flush mechanisms may be influential" (US EPA, 1991:8).

The NPDES standards were based on permits from the following Air Force bases and civilian airports:

Charleston AFB	Dayton International Airport
Ellsworth AFB	Salt Lake City International Airport
Kelly AFB	Stapleton International Airport
Robins AFB	
Tinker AFB	
Wurtsmith AFB	

TABLE 4

TYPICAL STORM WATER DISCHARGE CONCENTRATIONS

EFFLUENT CHARACTERISTICS	TYPICAL DAILY MAX. LIMITS (GRAB SAMPLES) (mg/l)	ACTUAL GRAB SAMPLE CONCENTRATIONS (mg/l)
TSS	40-50	55.00
BOD_5	20-30	10.10
COD	100-200	58.00
OIL AND GREASE	10-15	3.67
TOTAL PHOSPHATES (as phosphorous)	5	.39
AMMONIA (as nitrogen)	1	.77
TKN	2	1.80
LEAD	1	-
ZINC	2	-
COPPER	1	-
PHENOLS	.2	-
SURFACTANTS	10	-
ETHYLENE GLYCOL	15	-
pH	6-8.5	-

The oil and grease mean concentration is based only on grab sampling at .5 hours because this is the amount of time required to sample after the first rainfall. Also, the daily limit for ethylene glycol only applies to Stapleton International Airport. The Colorado Department of Health established a maximum concentration of 15 mg/l for ethylene glycol in any discharges. This discharge limitation was based on the estimated toxicity to children as a result of the ingestion of one liter of ethylene glycol/water mixture at that concentration. Since ethylene glycol has been determined to be toxic to humans and imparts relatively high BOD on the receiving water, maintaining glycol levels below 15 mg/l will help reduce these effects and improve the quality of

nearby surface water (Camp Dresser & McKee, 1987:4-3). It is anticipated that ethylene glycol will be regulated elsewhere in the near future and at much lower levels. The new Denver airport was already told to "plan for zero parts per million" for glycol emissions (McKenna, 1993a:44).

Another result worth noting is that the grab sampling data for BOD in Table 4 is well below the typical NPDES limits even though studies have shown that ethylene glycol is a major problem at most airports that implement deicing practices. For example, in February 1990, BOD levels in Lake O'Hare, which receives storm water runoff from Chicago O'Hare airport, exceeded 1,400 mg/l. Similar results were found at Denver's Stapleton Airport where glycol concentrations were monitored in excess of 5,000 mg/l with some concentrations exceeding 100,000 mg/l. Storm water samples from the Madison, Wisconsin, Truax Field had a BOD of 8,000 mg/l, while the State of Connecticut, in February 1989, measured the BOD to be 400-500 mg/l in runoff entering streams at Hartford International Airport. These high glycol levels have led to fish kills, low dissolved oxygen, high ammonia nitrogen, and odors in various receiving waters (Whitescarver and Mackenthun, 1990:7-8). Possible explanations for the low concentration of BOD in the AAAE survey are:

1. Sampling procedures do not dictate which time of the year to conduct the storm water sampling. Even though the sampling time frame was limited from April 1992 to March 1993, sampling may have been conducted during the summer months when deicing chemicals are not present in the storm water.

2. Although BOD and COD are considered indicators of elevated levels of glycol, testing may not have been specifically performed for glycol since a standard test for glycol has not yet been prescribed by the EPA.

3. EPA general permits for storm water discharge are flawed because they assume a relationship between aircraft operations and

facility usage of glycol. This assumption is reflected by the requirement of storm water sampling at airports with over 50,000 operations. Many large airports make little or no use of deicers while some smaller airports may make relatively extensive use of deicers. (AAAE, 1993:1)

Although EPA's general permit requires a description of potential pollutant sources which may be "reasonably expected to add significant amounts of pollutants to storm water discharges or which may result in the discharge of pollutants during dry weather from separate storm sewers draining the facility" (US EPA, 1992:2-7), not all industrial discharges are meeting this requirement. More detailed and more stringent monitoring procedures must be established in order to achieve a better characterization of the pollutants in the storm water runoff. Airfields where de-icing activities occur should expect to have higher BOD concentrations than those found in the AAAE survey.

USAF Airfield Storm Water Characteristics

The AAAE storm water data only included samples for the EPA's federal general permit monitoring requirements. These sampled pollutants include BOD_5, COD, phosphorous, nitrogen, TSS, and oil and grease. The AAAE survey was only concerned with these pollutants because they were common to all airports throughout the United States. Site-specific pollutants were not reported in the AAAE survey because the sample size would not be large enough to represent all civilian airports.

In addition to the AAAE pollutants, the National Urban Runoff Program (NURP) indicated other common pollutants of concern (e.g. heavy metals and bacteria). A BCE/EM should be aware of all possible pollutants at the installation, not just those that are regulated by the general permit. Site-specific pollutants must be considered as future storm water regulations become more stringent (even though the AAAE

survey did not recognize these pollutants). Therefore, the USAF airfield storm water pollutants to be used in the development of the decision support framework (DSF), presented in Chapter V, include both the general permit pollutants and the most common site-specific pollutants that may be of concern to BCEs/EMs. These pollutants are included in the first table of the DSF, entitled Pollutant Removal Effectiveness. It is anticipated that the aviation industry will face more stringent discharge limits and the Air Force should be prepared to meet these limits. The DSF will aid the BCE/EM in the selection of appropriate BMPs to effectively and efficiently meet future NPDES storm water requirements.

Current Innovative BMPs

BMPs are currently being constructed at many airfields throughout the country, but there is currently no data available from AFBs on their effectiveness (the sampling results from the AFBs applying for the group permit were not identified by outfall and, thus, the airfield could not be distinguished from the rest of the base). Some examples of BMPs currently planned or in experimental usage include:

- Sand Filters at National/Dulles Airports, Washington DC
- Constructed Wetlands at MacDill AFB, Hurlburt Field, and Whiteman AFB
- De-icing Fluid Recovery System at Griffis AFB
- Drive Through De-icing Facility at Westover AFB
- Series of collection ponds and runway trenches which incorporate multiple valves and switches for metered flow into the wastewater treatment plant at the New Denver Airport
- Gantry system in conjunction with a fluid recovery system for deicing fluids at the United Parcel Service hub in Louisville KY and at the New Denver Airport.
- Storm water system study which may indicate that containment measures are necessary to contain contaminants at Fairchild AFB
- Vehicle washracks connected to sanitary sewers, aircraft deicing area relocated from the north apron, and earthen berms built for sediment control at Kelly AFB
- Batts metered-flow deicing system for runway deicing at Eielson AFB
- $3.4 million storm water upgrade project, including the construction of a retention/detention basin and the addition of fuel-water separators, at Wright-Patterson AFB
- Air Combat Command (ACC) approved $1.5 million in fiscal year 1995 for storm drainage improvements at 7 Air Force bases. The improvements include diverting runoff, constructing

detention/retention ponds, installing oil/water separators, and repairing cross connections and infiltration systems. The bases include Ellsworth AFB, McConnell AFB, Fairchild AFB, Barksdale AFB, Beale AFB, Minot AFB, and Offutt AFB

A few storm water projects are currently being implemented while others are still in the programming stage and/or awaiting funding. ACC has taken the initiative to improve storm water quality before new NPDES standards are received from the EPA. This proactive approach is anticipated to carry over to the other major commands in the near future. It seems that the Air Force has begun to prepare itself for more stringent storm water discharge standards.

V. Decision Support Framework

Many factors must be considered before a successful storm water BMP program can be implemented. Such factors as cost, manpower and maintenance requirements, nonpoint source pollution removal effectiveness, and suitable site conditions are very important. Each BMP has unique capabilities and limitations that need to be evaluated. The first step in the BMP planning process is the determination of the goal. The goal answers the question of "What is this BMP supposed to accomplish?" At a minimum, implementation of the BMP should accomplish the following goals:

1. Reproduce, as nearly as possible, the hydrological conditions in the area prior to development.
2. Provide removal of non-point source pollutants.
3. Be appropriate for the site given physical constraints.
4. Be reasonably cost-effective in comparison with other BMPs and technologies.
5. Have an acceptable future maintenance burden.
6. Have a neutral or positive impact on the natural and human environment (Schueler, 1987:2.1-2.2).

To aid the Base Civil Engineer/Environmental Manager (planner) in the accomplishment of these goals, the storm water pollutants discussed in Chapter IV along with information in the literature review were used to develop the following Decision Support Framework (DSF). The DSF is a series of seven tables that rate a BMP's effectiveness with respect to different impact areas. Impact areas are defined as areas that must be considered when analyzing a BMP for implementation (e.g. watershed area, soil permeability, space consumption, erosion control, and pollutants). Some of the data in these tables were adapted from similar tables used by Thomas R. Schueler in Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. The remaining data was derived

from the discussion of other BMPs presented in the literature review in Chapter II. The seven tables should be used in reducing the number of alternative BMPs down to a few that may be appropriate to meet the goal. The tables used in the DSF are:

- Pollutant Removal Effectiveness (Table 5)
- Watershed Area (Table 6)
- Soil Permeability (Table 7)
- Storm Water Discharge Control (Table 8)
- Other Restrictions on BMPs (Table 9)
- Community Factors (Table 10)
- Economic Factors (Table 11)

Tables 6 and 7 rate the BMPs either feasible (which may be interpreted as good to excellent), marginal, or not feasible (poor). Tables 5 and 8-11 rate the BMPs using three symbols: a filled circle, half-filled circle, and an empty circle. Each chart has different definitions for the symbols (see charts for key), but the symbols have similar meanings across the board: a filled circle means the BMP is rated good to excellent in that area, a half-filled circle indicates the BMP is marginal, and an empty circle indicates the BMP is poor in that area. In some instances an "X" may be used to designate areas where insignificant or no data is available to rate the BMP.

Each table used in succession will narrow the appropriate BMP options. The tables may be used in any order although Table 5, Pollutant Removal Effectiveness, should normally be used first since the reduction of a pollutant to meet NPDES standards will usually be the highest concern for a BCE/EM. After progressing through all the charts for a given scenario, one or a few candidate BMPs will remain. These BMPs should be investigated in further detail to insure they will achieve the goal. Each of the tables is described in further detail below and definitions of table terms are included in Appendix A. Appendix B includes an example using the DSF.

Pollutant Removal Effectiveness. Storm water pollutant removal is the major screening factor for selecting appropriate BMPs. Table 5 illustrates the pollutant removal effectiveness of the BMPs and must be used to narrow appropriate options based on desired removal of a particular pollutant; if the BMP cannot achieve the desired pollutant removal, it should not be investigated further. The pollutants listed in Table 5 are the pollutants monitored in the American Association of Airport Executives' (AAAE) storm water survey along with pollutants discussed in the National Urban Runoff Program that may have possible effluent restrictions in future NPDES permits.

Watershed Area. The watershed that the BMP serves is a major factor to consider. Certain BMPs require large quantities of water to be successful while others could be overwhelmed if the flow is too large. The watershed area restrictions are illustrated in Table 6. Generally, detention ponds and wetlands require a large watershed while swales and filter strips require smaller areas. Impervious areas may need special consideration when estimating storm water runoff quantities; as a general rule of thumb during a one inch thunderstorm, an acre of pavement may yield the same amount of runoff as 20-100 acres of rangeland. This factor should be taken into account when estimating the quantity of storm water that needs treatment (Urbonas and Stahre, 1993:39).

Soil Permeability. The type of soil underlying the proposed BMP is also an important factor. Infiltration type BMPs (such as porous paving and infiltration trenches) require soils with high porosity and permeability. Table 7 graphically indicates the types of soils appropriate for each BMP. The table should help the engineer/manager narrow the options even further. For example, if the BMP selected in the first table were an infiltration basin and detention pond and the soil type in the area is a sandy clay, it should be obvious that the

infiltration basin is not suitable for that area, though the detention pond should be considered further.

Storm Water Discharge Control. BMPs also need to be screened based on the storm water benefits that they provide. Storm water management encompasses two aspects: 1) discharge control, which impacts volume, groundwater recharge and stream bank erosion; and 2) pollutant removal effectiveness. Discharge control involves four separate concepts:

1. Design storm periods
2. Volume Control
3. Groundwater recharge ability, and
4. Streambank erosion control.

Table 8 describes the BMP's ability to control discharges and should be used to further narrow the BMP options.

Other Restrictions on BMPs. Besides watershed area served and soil type, there are more restrictions on BMP selection and implementation. A few of these restrictions are: adjacent land slope, water table height, bedrock layer depth, proximity to foundations and walls, land consumption, frequency of storms, nearby land uses, sediment loading rates, and thermal characteristics. These restrictions must be investigated before a BMP can be selected. For example, if a detention pond is selected from the previous two tables, but there is not enough land to build the pond, this option would no longer be acceptable and another option must be investigated. Table 9 below graphically illustrates these common BMP restrictions.

Community and Economic Factors. Finally, BMPs need to be screened for other factors such as economic feasibility, safety, operations and maintenance requirements, and community acceptance. Other less quantifiable aspects such as habitat creation, landscape enhancement, and recreational benefits can also be screened. Tables 10 and 11 illustrate these factors for each BMP.

TABLE 5

POLLUTANT REMOVAL EFFECTIVENESS *

BMPs	TSS	BOD	COD	O&G	P	N	Ld	Zn	Cu	Bacteria
Grass Swales	◑	○	○	X	○	◑	◑	◑	○	X
Infiltration Basins	●	●	●	X	◑	◑	●	●	●	●
Infiltration Trenches	●	●	●	X	◑	◑	●	●	●	●
Filter Strips	●	◑	◑	X	◑	◑	●	●	●	X
Porous Paving	●	●	●	X	◑	◑	●	●	●	●
Injection Wells	X	X	X	X	X	X	X	X	X	X
Sedimentation Basin	◑	◑	◑	X	○	○	●	◑	X	●
Detention Pond	◑	◑	◑	X	○	○	●	◑	X	●
Retention Pond	◑	◑	◑	X	◑	◑	●	◑	X	●
Wetlands	●	●	◑	◑	●	●	●	○	○	●
Oil/Water Separators	○	○	○	●	○	○	○	○	○	○
Water Quality Inlets	○	○	○	○	○	○	○	○	○	X
Dissolved Air Flotation	◑	◑	◑	●	◑	◑	X	X	X	X
Slow Sand Filters	◑	◑	◑	○	◑	◑	X	◑	X	X
Rapid Sand Filters	◑	◑	◑	○	◑	◑	X	◑	X	X

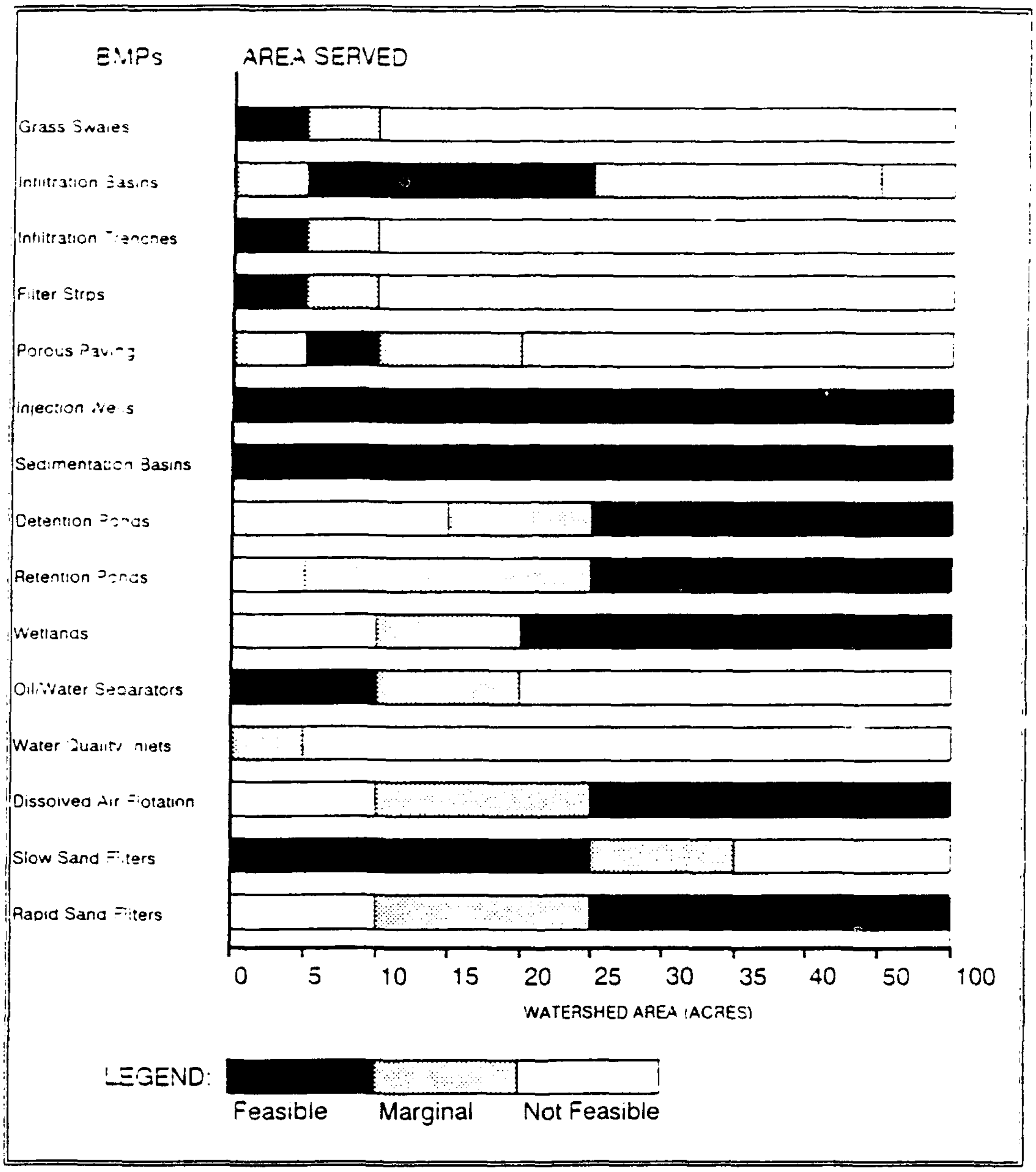
* All removals depend on the actual design. The removals shown are best case.

KEY:
- ○ —> 0 to 25% removal
- ◑ —> 25 to 75% removal
- ● —> 75 to 100% removal
- X —> Insufficient Knowledge

Terms found in Appendix A

TABLE 6

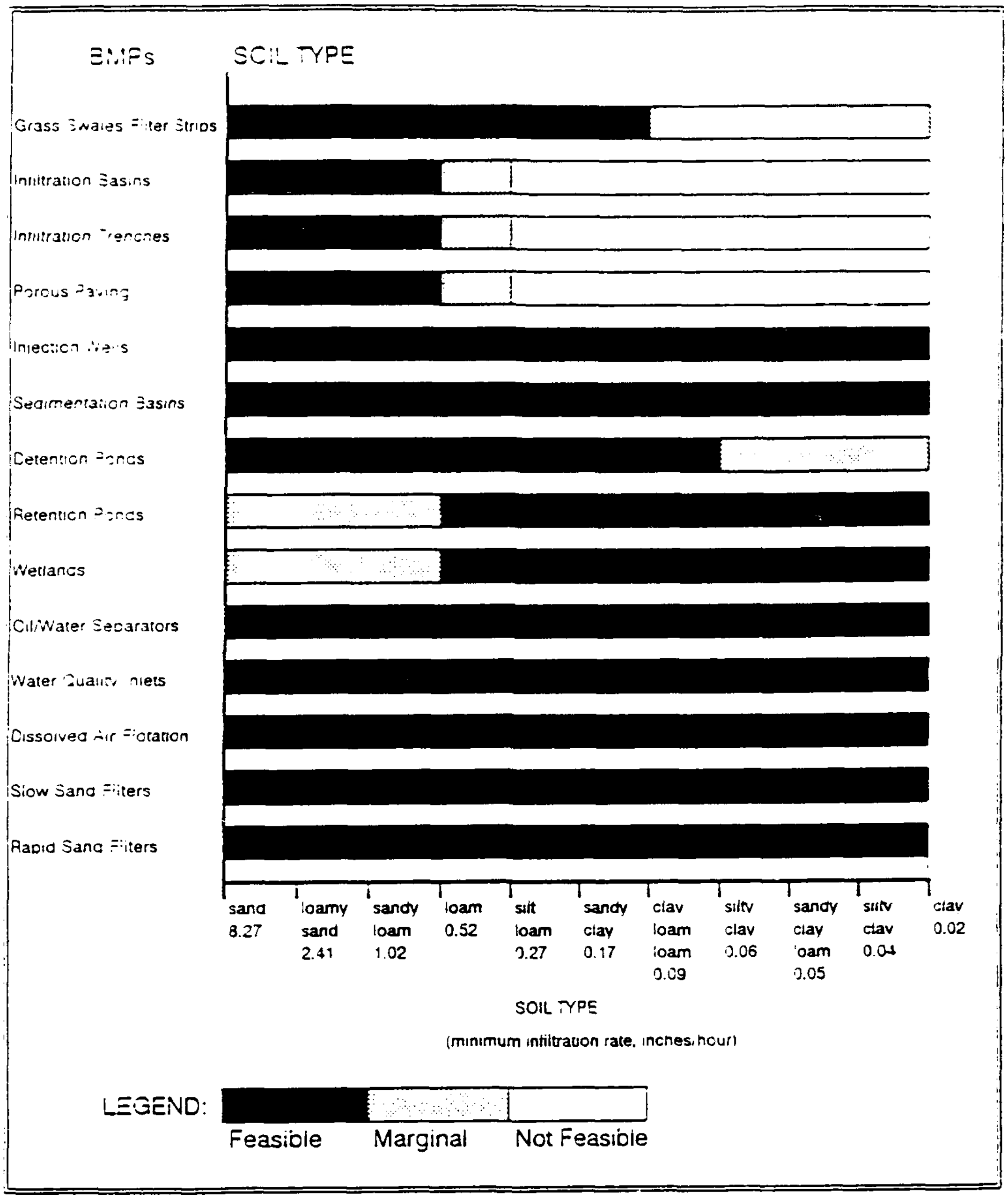
WATERSHED AREA



Terms found in Appendix A

TABLE 7

SOIL PERMEABILITY



Terms found in Appendix A

TABLE 8

STORM WATER DISCHARGE CONTROL

BMPs	2 YEAR STORM	10 YEAR STORM	100 YEAR STORM		VOLUME CONTROL		GROUNDWATER RECHARGE		STREAMBANK EROSION CONTROL
Grass Swales	◑	○	○		◑		◑		○
Infiltration Basins	●	◑	○		●		●		●
Infiltration Trenches	●	◑	○		●		●		●
Filter Strips	◑	○	○		◑		◑		○
Porous Paving	●	◑	○		●		●		●
Injection Wells	●	◑	○		○		●		○
Sedimentation Basin	●	◑	○		◑		○		○
Detention Pond	●	●	●		◑		○		●
Retention Pond	●	●	●		◑		○		●
Wetlands	●	●	●		◑		●		●
Oil/Water Separators	●	◑	○		○		○		○
Water Quality Inlets	○	○	○		○		○		○
Dissolved Air Flotation	●	◑	○		○		○		○
Slow Sand Filters	●	◑	○		○		○		○
Rapid Sand Filters	●	◑	○		○		○		○

KEY:
○ —> Seldom or never provided
◑ —> Sometimes provided w/ careful design
● —> Usually provided

Terms found in Appendix A

TABLE 9

OTHER RESTRICTIONS ON BMPs

BMPs	SLOPE	HIGH WATER TABLE	CLOSE TO BEDROCK	PROXIMITY TO FOUNDATIONS	SPACE CONSUMPTION	MAXIMUM DEPTH	RESTRICTED LAND USES	HIGH SEDIMENT INPUT	THERMAL POLLUTION
Grass Swales	○	○	◑	◑	●	●	○	○	●
Infiltration Basins	◑	○	○	◑	◑	○	●	○	●
Infiltration Trenches	○	○	○	◑	●	○	●	○	●
Filter Strips	◑	◑	◑	○	●	●	◑	○	●
Porous Paving	○	○	○	○	○	○	○	○	●
Injection Wells	◑	◑	○	●	◑	●	●	◑	●
Sedimentation Basin	●	●	●	●	○	◑	○	●	●
Detention Pond	●	●	◑	●	○	○	●	◑	●
Retention Pond	●	●	◑	●	○	○	●	◑	○
Wetlands	●	●	◑	●	○	●	○	●	○
Oil/Water Separators	○	○	◑	◑	●	◑	●	○	●
Water Quality Inlets	●	●	○	○	●	○	○	○	●
Dissolved Air Flotation	●	◑	◑	◑	○	◑	●	◑	●
Slow Sand Filters	●	●	●	◑	○	◑	●	◑	●
Rapid Sand Filters	●	●	●	◑	○	◑	●	◑	●

KEY:
○ —> May preclude the use of a BMP
◑ —> Can be overcome w/ careful site design
● —> Generally not a restriction

Terms found in Appendix A

TABLE 10

COMMUNITY FACTORS

BMPs	LOW FLOW MAINTENANCE	STREAMBANK EROSION CONTROL	AQUATIC HABITAT CREATION	WILDLIFE HABITAT CREATION	NO THERMAL POLLUTION	LANDSCAPE ENHANCEMENT	RECREATIONAL BENEFITS	HAZARD REDUCTION	AESTHETICS	COMMUNITY ACCEPTANCE
Grass Swales	◐	○	○	◐	●	◐	○	●	◐	●
Infiltration Basins	●	◐	○	●	●	◐	◐	●	○	◐
Infiltration Trenches	●	◐	○	○	●	○	○	●	○	●
Filter Strips	◐	○	○	●	●	◐	○	●	◐	●
Porous Paving	●	◐	○	○	●	○	○	●	○	●
Injection Wells	○	○	○	○	●	○	○	◐	○	◐
Sedimentation Basin	○	◐	○	○	●	○	○	◐	◐	◐
Detention Pond	○	●	◐	●	●	◐	◐	◐	◐	◐
Retention Pond	○	●	●	●	○	●	●	◐	◐	●
Wetlands	○	●	●	●	○	●	◐	◐	◐	◐
Oil/Water Separators	○	○	○	○	●	○	○	○	◐	◐
Water Quality Inlets	○	○	○	○	●	○	○	●	○	●
Dissolved Air Flotation	○	○	○	○	●	○	○	◐	○	◐
Slow Sand Filters	○	○	○	○	●	○	○	◐	◐	◐
Rapid Sand Filters	○	○	○	○	●	○	○	◐	◐	◐

KEY:
○ —> Seldom provided
◐ —> Sometimes provided (w/ design modifications)
● —> Usually provided

Terms found in Appendix A

TABLE 11

ECONOMIC FACTORS

BMPs	CONSTRUCTION COSTS	OPERATING COSTS	MANPOWER REQUIREMENTS	OPERATOR EXPERTISE	EQUIPMENT	MAINTENANCE
Grass Swales	◑	●	X	X	X	◑
Infiltration Basins	○	◑	X	●	X	◑
Infiltration Trenches	◑	◑	X	●	X	◑
Filter Strips	◑	●	X	X	X	◑
Porous Paving	○	◑	●	◑	◑	●
Injection Wells	◑	◑	X	○	○	○
Sedimentation Basin	○	◑	●	◑	●	◑
Detention Pond	○	●	X	●	●	◑
Retention Pond	○	●	X	●	●	◑
Wetlands	◑	●	X	●	○	●
Oil/Water Separators	◑	◑	●	◑	◑	◑
Water Quality Inlets	◑	◑	●	●	◑	◑
Dissolved Air Flotation	○	○	○	○	○	○
Slow Sand Filters	◑	○	○	◑	◑	◑
Rapid Sand Filters	○	○	○	○	○	○

KEY:
- ○ --> High cost
- ◑ --> Medium cost
- ● --> Low cost
- X --> No cost

Terms found in Appendix A

There are many factors that are rated in the charts and it is the planners responsibility to determine which factors need consideration; for example, if pollution removal is extremely important, BMPs that rate poor in the desired pollution removal categories would not be suitable for implementation. If at the same time, the BMP rates poor on volume control and excellent in pollution removal and volume control is not a concern, then the BMP should be considered further. For the DSF to be effective, the planner must determine which impact areas need to be considered. Appendix B gives an example problem using the DSF to select BMPs for possible implementation.

After reading the example problem, it should be obvious that BMP selection is a complicated process. Seldom, if ever, will a BMP receive excellent ratings across the board. The planner must decide which areas are critical for successful BMP implementation and use those areas as decision points. If a BMP is rated "poor" in a critical area, it may have to be eliminated from further consideration. As illustrated in Appendix B, multiple marginal ratings may also eliminate a BMP. It is also possible that a BMP may not satisfy all the requirements of a given problem; in that case, a series of BMPs may be required to achieve the storm water goals.

In choosing the appropriate BMP, the Base Civil Engineer/Environmental Manager must take all these considerations into account and assign importance to each characteristic. This should be accomplished before a BMP is selected for implementation. It is extremely important that the purpose(s) of the storm water management project is known before a BMP is selected for implementation. Without the specific purpose(s) of the project, the selection of the appropriate BMP is impossible.

The charts above may be used to effectively reduce the BMP options down to a few good candidates for implementation. Many impact areas need to be considered before a BMP is selected. It is the planner's

responsibility to assign importance to the factors listed in the figures. A sound engineering analysis is required before any BMP is planned or implemented. These charts will aid this analysis process, but they will not replace it. This Decision Support Framework is a tool to aid the Base Civil Engineer/Environmental Manager in BMP selection.

VI. Conclusions and Recommendations

The purpose of this research was to analyze storm water best management practices (BMPs) to assist Base Civil Engineers and Environmental Managers in complying with National Pollutant Discharge Elimination System (NPDES) storm water discharge requirements for airfield pavements. This chapter presents the overall conclusions to the investigative questions presented in Chapter I, as well as some recommendations for future research.

Conclusions

Investigative Question One. What are the applicable rules and regulations associated with storm water runoff at airfields?

Congress passed the Clean Water Act (CWA) of 1977 to restore and maintain the chemical, physical, and biological integrity of water in the United States. The Water Quality Act of 1987 was later passed to improve water quality further, partially because merely controlling point sources was insufficient to meet the CWA's water quality goals. The discharge of any pollutant into navigable waters was prohibited unless the discharge was authorized by a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permits identify and establish effluent limitations for pollutants that can be discharged in storm water runoff and can possibly be used to mandate the use of appropriate BMPs. NPDES permits can take the form of individual, group, or general permits.

The Environmental Protection Agency (EPA) was given the responsibility to establish NPDES permit requirements for storm water discharges associated with industrial activity. On November 16, 1990, the EPA began to implement these regulations. All United States Air Force (USAF) bases are categorized as industrial dischargers and must

comply with storm water standards and criteria established by the EPA. The most commonly regulated parameters include oil and grease, BOD_5, COD, TKN, and TSS. The primary components of de/anti-icing materials are beginning to be regulated and are of major importance to the AF in the future. The State of Colorado has already begun to require a permit for the discharge of ethylene glycol and anticipates a zero discharge standard in the future.

It is anticipated that future permitting priorities of the EPA and the states will focus on airports because the deicing of aircraft and runways and oil and fuel spills on aprons, taxiways and runways pollute nearby surface waters. The USAF must be prepared to meet future NPDES requirements to prevent violations, large fines, and/or restrictions on routine airfield activities.

Investigative Question Two. What are the types and levels of storm water pollutants generated from airfield activities?

Industrial pollutants are generated from a variety of daily activities at an airfield. The Nationwide Urban Runoff Program (NURP) found heavy metals, coliform bacteria, and total suspended solids to be the most prevalent water pollutants due to nonpoint sources. An EPA study identified transportation activities as producers of inorganic chemicals and heavy metals (including copper, lead, and zinc), as well as petroleum products from spills and leaks. Other pollutants, primarily generated during the cleaning and washing of aircraft and ground/maintenance vehicles, are acids and alkalies, organic solvents and phenols, oil and grease, and de/anti-icing chemical wastes.

Based on a survey of the American Association of Airport Executives, the pollutants noted above were found, on the average, to be within the NPDES permitted levels except for total suspended solids. The newest concern, though, is the control of glycols and urea because of their aquatic toxicity, oxygen depletion and organic enrichment of receiving waters, and obnoxious odors. Although the BOD, COD, and

nutrient levels appear to be within NPDES limits, there is concern that AAAE surveyed airports did not include samples taken during the winter months when de-icing chemicals are prevalent.

Investigative Question Three. What management practices can be implemented at USAF airfields to ensure compliance with future NPDES storm water requirements?

BCEs/EMs must find the best combination of BMPs to control or prevent a pollutant from entering the surface water. Integrating these nonstructural, low-structural, and structural measures into an effective system is a difficult task, but one that can be overcome with proper planning, control and implementation.

Nonstructural measures usually include good housekeeping (such as street sweeping), pollution prevention, and land-use planning. Low-structural measures typically include soil protection and stabilization, berms, and protective dikes. Structural measures, broadly categorized as treatment technologies, include infiltration systems (grass swales, infiltration basins and trenches, filter strips, and porous pavements), detention systems (sedimentation basins, detention/retention ponds, and wetlands), and flow-through treatment facilities (oil/water separators, water quality inlets, dissolved air flotation, and sand filters).

As future water quality objectives are adopted and sufficient sampling data is gathered, BMPs designed to meet today's standards may not be sufficient. The decision support framework (DSF) presented in Chapter V is a starting point for BCEs/EMs that are attempting to find the optimal BMP to control or prevent storm water pollution. The DSF considers: pollutant removal effectiveness, watershed area, soil permeability, storm water discharge controls, BMP restrictions, and community and economic factors. These tables, when used in succession, aid a BCE/EM in the decision-making process to achieve the storm water goals.

Recommendations for Future Research

This research was prompted by the anticipation of more stringent NPDES storm water requirements. The Air Force must be able to identify and assess potential and existing sources of storm water contamination. The proper measures to eliminate or reduce these pollutants must then be selected to meet the NPDES requirements. In order for smooth implementation of these BMPs, a few subjects may require future research.

1. Using the DSF information provided here, create an expert system/computer model that can step a BCE/EM through a decision framework in order to provide options to control or prevent storm water pollution.

2. Once the NPDES standards are released for the Air Force group permit, determine which specific BMPs are capable of reducing storm water pollutants to their regulated levels.

3. Obtain data on fully implemented or pilot storm water management projects that use innovative technologies and perform a cost-benefit analysis to determine the actual removal effectiveness and feasibility of various BMPs.

4. Since de/anti-icing chemical wastes are a current concern, a study may be appropriate that obtains storm water monitoring data from airfields/airports to correlate the ethylene glycol concentration with storm water flow and weather conditions. This may help to establish design criteria for BMPs where de/anti-icing activities are prevalent.

Appendix A: DSF Terms

The following definitions and explanation of terms were obtained from Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs by Thomas R. Schueler and used in Tables 7-10.

Table 5 Terms: See literature review and Appendix C for definitions.

TSS - total suspended solids

BOD - biochemical oxygen demand

COD - chemical oxygen demand

O&G - oil and grease

P - phosphorous

N - nitrogen

Ld - lead

Zn - zinc

Cu - copper

Bacteria - bacteria levels

Table 8 Terms:

Design Storm (2, 10, 100 Year Storm) - The design storm is the flood that occurs, on average, every 2, 10, or 100 years. In natural watersheds, the two year storm produces a flood that fills a stream to the top of its banks. Peak discharge control is accomplished by detaining a large portion of the runoff volume and then releasing it at the lower pre-development rate.

Volume Control - Volume control refers to the BMP's ability to reduce the quantity of runoff. Since infiltration BMPs divert runoff into the ground, these BMPs reduce the quantity of runoff. On the other hand, flow through BMPs have little effect on runoff quantity.

Groundwater Recharge - Groundwater recharge refers to the BMP's ability to recharge groundwater levels. Infiltration BMPs are an excellent means of providing ground water recharge.

Streambank Erosion Control - Streambank erosion control is the ability of the BMP to protect downstream erosion. Any BMP that temporarily detains or decreases the quantity of runoff has the ability to decrease downstream erosion.

Table 9 Terms:

Slope - Steep land slopes may restrict the use of several BMPs. For example, swale slopes should not exceed 5%.

High Water Table - The water table can act as an effective barrier to exfiltration and can reduce the ability of an infiltration BMP.

Close to Bedrock - Exfiltration is also impeded if the bedrock layer lies close to the soil surface. A close bedrock layer may prevent an infiltration BMP from draining properly.

Proximity to Foundation and Wells - Infiltration BMPs may cause local seepage problems. Infiltration BMPs located near foundations may cause basement flooding. Infiltration BMPs located near wells may contaminate groundwater supplies.

Space Consumption - Various BMPs require land to be effective; areas with limited space may preclude the use of several BMPs.

Maximum Depth - If infiltration rates of underlying soils is marginal, the depth of the infiltration facility may preclude its use. For example, in highly permeable soil, a five foot deep trench may be effective; to get the same effectiveness in a less permeable soil, the depth may need to be 100 feet.

Restricted Land Use - BMPs can only be applied to particular land uses and are not broadly applicable for all sites. For example, porous pavement should only be used in light traffic areas such as parking lots.

High Sediment Input - Infiltration BMPs are susceptible to rapid clogging and subsequent failure if significant sediment loads are allowed to enter the structure. Construction activities should be controlled to reduce sediment inputs.

Thermal Pollution - Some BMPs that detain water are susceptible to temperature increases during the summer months. These BMPs should be avoided in watersheds with sensitive cold-water streams.

Table 10 Terms:

Low Flow Maintenance - Downstream aquatic life can be jeopardized when the natural low flow levels experienced during the summer months decline even further because of reduced infiltration in urbanized watersheds. Infiltration BMPs appear to be capable of sustaining low flows due to groundwater flow effects.

Streambank Erosion Control - Streambank erosion control is the ability of the BMP to protect downstream erosion. Any BMP that temporarily detains or decreases the quantity of runoff has the ability to decrease downstream erosion.

Aquatic Habitat Creation - Refers to the BMP's ability to create aquatic habitats.

Wildlife Habitat Creation - Refers to the BMP's ability to create terrestrial wildlife habitats.

No Thermal Pollution - Refers to the BMP's ability of maintaining the runoff's natural temperature.

Landscape Enhancement - Refers to the BMP's ability to become an attractive feature o the community.

Recreational Benefits - Refers to the BMP's ability to add recreational benefits such as boating, fishing, hunting, swimming, etc. Only large retention ponds have the ability to provide excellent recreational benefits.

Hazard Reduction - High rates of urban runoff can cause safety problems downstream and some BMPs may reduce these hazards; others such as retention ponds may produce safety hazards. Careful design must be used to reduce and minimize new safety hazards.

Aesthetic Value - Refers to the BMP's ability to be an attractive feature in the community. All BMPs need careful design to insure positive aesthetic benefits.

Community Acceptance - Most BMPs are acceptable if regular cosmetic maintenance is performed.

Table 11 Terms:

Terms used in table 11 are common economic factors that affect any construction project. The break down of the impact factors were developed by the authors. Description of the impact factors follow:

Construction costs: the amount of money and resources required to implement/construct the BMP.

- High Cost - MILCON construction project
- Medium Cost - Base O&M account
- Low Cost - Changes in standard operating procedure

Operating costs: the amount of money required to keep the BMP in working order.

- High Cost-- over $100,000 per year
- Medium Cost-- $1000 to $100,000 per year
- Low Cost-- $1 to $1,000 per year
- No Cost

Manpower requirements: additional personnel required to operate the BMP.

- High-- three or more additional personnel required
- Medium-- two additional
- Low-- one additional
- None-- no additional personnel required

Operator expertise: the amount of training and knowledge required to operate the BMP.

- High-- significant amounts of training and experience required. Needs yearly training updates and experienced skilled labor.
- Medium-- moderate amounts of training but little or no experience required. Needs skilled labor and some training updates.
- Low-- little to no training required. Unskilled labor.
- None-- does not require operators

Equipment: the amount of equipment required for BMP operation.

- High-- over $50,000 and large quantities of equipment
- Moderate-- $10,000 to $50,000
- Low-- $0 to $10,000
- None-- no equipment required

Maintenance: the amount of maintenance required to insure proper operation of the BMP.

- High-- daily maintenance required
- Moderate-- weekly maintenance
- Low-- monthly maintenance
- Very low-- yearly maintenance
- None-- no maintenance required

Appendix B: Example Problem

The new NPDES storm water permit for Brooklyn AFB puts severe restrictions on effluent limits of suspended solids, oil and grease, heavy metals, and BOD. To meet your new permit levels, you will have to decrease suspended solids by 60%, oil and grease by 90%, lead by 95%, and BOD by 50%. The current discharge area serves a watershed area of approximately 30 acres, the dominant soil type is sandy loam, the adjacent land slope varies from 0%-8% but there are no land space restrictions. Downstream erosion is a major concern and storm water discharge rates need to be controlled. Local authorities require storm water facilities be designed for the 10 year storm. The base commander also thinks it would be nice to use base O&M funds but MILCON projects should not be disqualified. He is also an avid bird watcher so the creation of wildlife habitat is a benefit. Another problem is the base hiring freeze will not allow any additional employees. Using the charts of the Decision Support Framework, select appropriate BMPs for possible implementation.

Step 1

The first step in using the framework is to set the goal of the proposed project and its relevant impact areas. The goal in this case is to meet the NPDES permit levels. The relevant impact areas are pollution removal effectiveness, 30 acre watershed area, sandy loam soil, land slope, downstream erosion control, 10 year design storm, funds, habitat creation, and manpower requirements. To meet these requirements, the decision support framework can be used to narrow the BMP choices to a few good candidates. Following is the listed impact areas and the tables that are appropriate.

Impact Areas	Appropriate Table
Pollutant Removal	Table 5
Watershed Area	Table 6
Sandy Loam Soil	Table 7
Land Slope	Table 9
Ten Year Storm	Table 8
Volume Control	Table 8
Erosion Control	Table 8
Habitat Creation	Table 10
Costs	Table 11
Manpower	Table 11

Step 2

Use Table 5, Pollution Removal Effectiveness, to create the initial list of BMPs. The areas of concern in this chart are a reduction of suspended solids by 60%, oil and grease by 90%, lead by 95%, and BOD by 50%. Using Table 5 to evaluate the BMPs, we find:

	TSS	O&G	Metals	BOD
Grass Swales	25-75%	no data	25-75%	0-25%
Infiltration Basins	75-100%	no data	75-100%	75-100%
Infiltration Trench	75-100%	no data	75-100%	75-100%
Filter Strips	75-100%	no data	75-100%	25-75%
Porous Paving	75-100%	no data	75-100%	75-100%
Injection Wells	no data	no data	no data	no data
Sedimentation Basin	25-75%	no data	25-75%	25-75%
Detention Pond	25-75%	no data	75-100%	25-75%
Retention Pond	25-75%	no data	75-100%	25-75%
Wetland	75-100%	25-75%	75-100%	75-100%
Oil/Water Separator	0-25%	75-100%	0-25%	0-25%
Water Quality Inlet	0-25%	0-25%	0-25%	0-25%
DAF	25-75%	75-100%	25-75%	25-75%
Slow Sand Filter	25-75%	0-25%	25-75%	25-75%
Rapid Sand Filter	25-75%	0-25%	25-75%	25-75%

Oil and grease may effect BMP effectiveness; it may be necessary to install oil/water separators at critical points in the system to meet the oil and grease requirement. The BMPs with no data for oil and grease should still be considered with the premise that oil/water separators may be installed to handle the oil and grease problem. From the above list, the following BMPs should be considered further:

- Infiltration Basins
- Infiltration Trenches
- Filter Strips
- Porous Paving
- Injection Wells
- Detention Pond
- Retention Pond
- Wetland
- Oil/Water Separator

Step 3

Use Table 6, Watershed Area, to narrow the list of BMPs from Step 2. All BMPs listed "feasible" or "marginal" should still be considered at this time. BMPs rated "not feasible" should be eliminated at this time because they are not suited for the large watershed area. The user of these tables must use their best judgement to disqualify a BMP from further consideration if it continues to receive poor or marginal ratings while others continue to receive good or feasible ratings. Using Table 6 and a 30 acre watershed, we find:

Infiltration Basins - Marginal
Infiltration Trenches - Not Feasible
Filter Strips - Not Feasible
Porous Paving - Not Feasible
Injection Wells - Feasible
Detention Pond - Feasible
Retention Pond - Feasible
Wetland - Feasible
Oil/Water Separator - Not feasible

The candidate BMP list now consists of the following:

Infiltration Basin
Injection Wells
Detention Pond
Retention Pond
Wetland

The oil and grease (O&G) removal capabilities of the above BMPs is unknown. To combat the O&G problem, O&G pollution needs to be prevented at the source and/or oil/water separators need to be strategically installed at storm water inlets to stop its migration.

Step 4

The above list should now be narrowed further by using Table 7, Soil Permeability. The dominant soil type is sandy loam. The results from Table 7 are:

Infiltration Basin - Feasible
Injection Wells - Feasible
Detention Pond - Feasible
Retention Pond - Marginal
Wetland - Marginal

All the above BMPs should still be considered further.

Step 5

Table 9, Other Restrictions on BMPs, should now be used. The major restriction on this chart is land slope. From the chart we find:

Infiltration Basins - Marginal
Injection Wells - Marginal
Detention Pond - no restriction
Retention Pond - no restriction
Wetland - no restriction

All BMPs should still be considered further.

Step 6

Table 8 will be used to further narrow the list. The areas of concern here are the 10 year storm, volume control, and streambank erosion control.

	10 Year Storm	Volume Control	Erosion Control
Infiltration basin	Marginal (M)	G	G
Injection Wells	M	G	G
Detention Pond	Good (G)	M	G
Retention Pond	G	M	G
Wetland	G	M	G

The 10 year storm criteria is the major factor in this chart due to local regulations requiring storm water project to be designed for that storm. Based on that criteria and the marginal ratings they received in the previous step, infiltration basins and injection wells can now be removed from the list for further consideration. The remaining BMPs to be considered are:

Detention Ponds
Retention Ponds
Wetlands

Step 7

Table 10 deals with Community Factors. Since the Base Commander is a bird watcher, habitat creation is a concern and as always, so is landscape enhancement. From Table 10, we find:

	Habitat Creation	Landscape Enhancement
Detention Pond	Good	Marginal
Retention Pond	Good	Good
Wetlands	Good	Good

From the table, retention ponds and wetlands are rated "good" in both areas. The detention pond is only rated "good" in wildlife habitat creation. Because of that, the list of possible BMPs narrows to only retention ponds and wetlands.

Step 8

Table 11, Economic Factors, is the final chart. The selected BMP must not require any additional manpower and, if possible, base O&M funds should be used for the construction.

Retention Pond - may require MILCON but no extra manpower
Wetlands - may be built with O&M funds and requires no additional manpower

Conclusion

A summary of the sample problem analysis is illustrated in Table 12. Given the constraints of the situation, the charts in the decision support framework narrowed the options for storm water compliance to either a retention pond or a wetland. The problem still exists with meeting the oil and grease discharge limits. The oil and grease issue must be addressed with the possibility of adding oil/water separators at critical inlets. A detailed analysis should be conducted on the retention pond and wetland to insure that proper design, pollutant removal, safety, and other relevant design criteria are met. The cost of the projects will be dependent on many factors including size, discharge quantity, and location.

TABLE 12

EXAMPLE PROBLEM

BMPs	POLLUTANT REMOVAL	WATERSHED AREA	SANDY LOAM SOIL	LAND SLOPE	10 YEAR STORM	VOLUME CONTROL	EROSION CONTROL	COMMUNITY FACTORS	CONSTRUCTION COSTS	MANPOWER
Grass Swales	○	X	X	X	X	X	X	X	X	X
Infiltration Basins	●	◑	●	◑	◑	●	●	X	X	X
Infiltration Trenches	●	○	X	X	X	X	X	X	X	X
Filter Strips	●	○	X	X	X	X	X	X	X	X
Porous Paving	●	○	X	X	X	X	X	X	X	X
Injection Wells	●	●	●	◑	◑	●	●	X	X	X
Sedimentation Basin	○	X	X	X	X	X	X	X	X	X
Detention Pond	●	●	●	●	●	◑	●	◑	X	X
Retention Pond	●	●	◑	●	●	◑	●	●	◑	●
Wetlands	●	●	◑	●	●	◑	●	●	●	●
Oil/Water Separators	●	○	X	X	X	X	X	X	X	X
Water Quality Inlets	○	X	X	X	X	X	X	X	X	X
Dissolved Air Flotation	○	X	X	X	X	X	X	X	X	X
Slow Sand Filters	○	X	X	X	X	X	X	X	X	X
Rapid Sand Filters	○	X	X	X	X	X	X	X	X	X

KEY:
○ --> Poor
◑ --> Marginal
● --> Good
X --> Eliminated in previous step

Appendix C: Glossary

Best Management Practices (BMPs) are measures or practices used to reduce the amount of pollution entering surface water, air, land, or ground water. BMPs may take the form of a process, activity, or physical structure (US EPA, 1992c:1-4).

Biochemical Oxygen Demand (BOD_5) is defined as the amount of oxygen consumed during microbial degradation of organics after five days.

Chemical Oxygen Demand (COD) is defined as the oxygen equivalent of organic matter that can be oxidized using a strong chemical oxidizing agent.

Composite Samples are used to determine "average" loadings or concentrations of pollutants. Such samples are collected at regular time intervals and averaged into one sample. They can be developed by compositing flow rates (US EPA, 1993:37).

Decision Support Framework (DSF) is a graphical aid to Base Civil Engineers/Environmental Managers in the selection of appropriate BMPs to effectively and efficiently meet NPDES storm water requirements. Factors to be considered include watershed area, soil permeability, other restrictions on BMPs, storm water discharge control, pollutant removal effectiveness, and community and economic factors.

Detention Ponds are an example of a detention system that detains runoff in order to reduce the maximum discharge rate. They are designed to capture storm water and slowly discharge the water over a designed period and then emptied out. Retention ponds are similar, except they always store a designated quantity of water (Urbonas and Stahre, 1993:436).

Detention Systems are facilities that temporarily detain storm water runoff in order to reduce the peak flow rate and remove sediments. Examples include sedimentation basins, detention/retention ponds, and wetlands (Urbonas and Stahre, 1993:256).

Discharge is defined as a release or flow of storm water or other substances from a conveyance or storage container (US EPA, 1992c:B-2).

Dissolved Air Flotation is a flow-through treatment facility similar to sedimentation except that light weight particles are floated to the surface via micro-bubbles instead of settled by gravity (Zabel, 1985:42).

Fecal Coliform are minute living organisms, referred to as coliform bacteria, that originate in human or animal feces that are used as an indirect indicator of the other disease causing bacteria found in water (Viessman and Hammer, 1985:250).

Filter strips are usually long and relatively narrow areas of undisturbed or planted vegetation used to retard or collect sediment for the protection of watercourses, reservoirs, or adjacent properties (US EPA, 1992c:B-2).

First-Flush Sample is an individual sample taken during the first 30 minutes of a storm event. The pollutants in this sample can often be used as a screen for non-storm water discharges since such pollutants are flushed out of the system during the initial portion of the discharge.

Flow-Through Treatment Facilities are systems that treat storm water as it flows through the structure. Examples include oil/water separators, water quality inlets, dissolved air flotation, and sand filters.

Grab Samples are discrete samples which are taken from a waste stream on a one-time basis within the first 30 minutes of a discharge and with no regard to flow or time (US EPA, 1993:37).

Heavy Metals refer, chemically speaking, to metals with a specific gravity greater than about 4 or 5, but more often, the term is simply used to denote metals that are toxic. This includes aluminum, arsenic, beryllium, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, strontium, thallium, tin, titanium, and zinc (Masters, 1991:114).

Infiltration is a land application technique where large volumes of water are applied to land, then allowed to penetrate the surface and percolate through the underlying soil. Examples include swales, infiltration basins and trenches, filter strips, porous pavement, and injection wells (US EPA, 1992c:B-3).

Inlet is defined as an entrance into a ditch, storm sewer, or other waterway (US EPA, 1992c:B-3).

Injection Well is an infiltration system that injects storm water from a catchment basin under pressure into the groundwater strata (URS, 1977:153).

Low-Structural BMPs are controls that use natural land features with minor modifications, and small, simple structures such as earthworks and outlet devices (Finnemore, 1982:836).

National Pollutant Discharge Elimination System (NPDES) is the EPA's program to control the discharge of pollutants to waters of the United States [see 40 CFR 122.2 for further guidance] (US EPA, 1992c:B-4).

Nonpoint Sources are diffuse sources of pollution resulting from land runoff, precipitation, drainage, or seepage, rather than a pollutant discharge from a single location (GAO, 1990:8).

Nonstructural BMPs are controls that usually involve little or no construction and typically require small-to-moderate capital investments (Walesh, 1989:392).

NPDES Permit is an authorization, license or equivalent control document issued by the EPA or an approved State agency to implement the requirements of the NPDES program (US EPA, 1992c:B-4).

Oils and Grease (O&G) includes a wide variety of organic compounds having different physical, chemical, and toxicological properties. Common sources are petroleum derivatives and fats from vegetable oil and meat processing (Viessman and Hammer, 1985:239).

Oil/Water Separator is a device which removes oil and grease from water flows entering the drain (US EPA, 1992c:B-4).

Organic Pollutants are substances containing carbon which may cause pollution problems in receiving streams (US EPA, 1992c:B-4).

Organic Solvents are liquid organic compounds capable of dissolving solids, gases, and liquids (US EPA, 1992c:B-4).

pH a is number denoting the common logarithm of the reciprocal of the hydrogen ion concentration. A pH of 7.0 denotes neutrality, higher values indicate alkalinity, and lower values indicate acidity (James and others, 1991:42).

Phenols are industrial compounds used primarily in production of synthetic polymers, pigments, and pesticides, and occur naturally in fossil fuels (Viessman and Hammer, 1985:231).

Point sources are discrete points from which pollutants are or may be discharged (Cheremisinoff, 1990:203).

Pollutants are dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt or industrial, municipal, and agricultural waste discharged into water (US EPA, 1992c:B-5).

Pollution is the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water.

Porous Pavement is a man-made surface that allows water to penetrate through and percolate into the soil. Water seeps into lower layers of gravel for temporary storage and then naturally into the soil (US EPA, 1992c:B-5).

Retention Ponds detain runoff in a basin without release, except by means of evaporation, infiltration, or bypass (US EPA, 1992c:B-6).

Runoff is the part of precipitation or snow melt that runs off the land and into surface water (US EPA, 1992c:B-7).

Sand Filters are flow-through treatment facilities consisting of a water tight box with and underdrain system that filters out the pollutants. A "schmutzdecke" is the thin layer of biologically active micro-organisms that breakdown organic matter in the filter and help retain other solids more effectively (Martin and Martin, 1991:21-22).

Sedimentation Basins are detention systems, usually constructed of concrete, that rely on gravity to separate suspended materials from aqueous solutions (Montgomery, 1985:135-137).

Sediments are soil, sand, and minerals washed from land into water, usually after rainfalls (US EPA, 1992c:B-7).

Silviculture is a nonpoint source pollution category that is associated with forestry or timber harvesting activities (Praner and Sprewell, 1992:11).

Storm water consists of runoff from storm events, snow melt, and surfaces (US Congress, 1990:47995).

Storm Water Discharge Associated with Industrial Activity is a discharge from any conveyance which is used for collecting and conveying storm water which is directly related to manufacturing, processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)] (US EPA, 1992c:B-8).

Structural BMPs can be defined as major public works projects and as such require moderate to major planning and design efforts, formal approval by one or more government units or agencies, letting of construction contracts, and moderate-to-large capital investments and operation and maintenance commitments (Walesh, 1989:392).

Surface water is defined as all water naturally open to the atmosphere. Examples include lakes, rivers, streams, seas, reservoirs and wetlands (US EPA, 1992c:B-10).

Swales are shallow grassed ditches that are at least seasonally wet, usually heavily vegetated, and normally without flowing water. They direct storm water flows into primary drainage channels and allow some of the water to infiltrate into the ground (US EPA, 1992c:B-10).

Total Kjeldahl Nitrogen (TKN) is total the concentration of organic and ammonia nitrogen and is a good indicator of nitrogen loading levels (Masters, 1991:126; Praner and Sprewell, 1992:25,159).

Total Nitrogen is defined as nitrate plus nitrite.

Total Suspended Solids (TSS) is defined as the portion of total solids that can be removed by a membrane filter with a pore size of 1.2 micrometers.

Water Quality Inlets prevent floating debris from entering the storm sewer system and typically serve small parking lots (Schueler, 1987:8.1).

Wetlands are areas that are regularly saturated by surface or ground water and subsequently are characterized by vegetation that is adapted for life in saturated soil conditions (US EPA, 1992c:B-11).

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This research analyzed storm water best management practices (BMPs) that may assist Base Civil Engineers/Environmental Managers in complying with National Pollutant Discharge Elimination System (NPDES) storm water discharge requirements for Air Force airfield pavements. As a result of recent storm water regulations issued by the Environmental Protection Agency, increased emphasis has been placed on preventing and controlling the discharge of pollutants into surface waters of the United States. Based on the results of an American Association of Airport Executives' survey of civilian airports, the types and levels of airfield pollutants were identified. Typical NPDES storm water permit standards were then established based on actual permits from Air Force bases and civilian airports. A thorough literature search revealed the nonstructural, low-structural, and structural BMPs capable of eliminating or reducing storm water pollutants. Finally, a Decision Support Framework (DSF) was introduced that guides a decision-maker through a series of tables that narrows the appropriate BMP options for a particular site or installation. The DSF encompasses factors such as pollutant removal effectiveness, watershed area, soil permeability, storm water discharge controls, restrictions on BMPs, and community and economic factors.

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